EDITION A

The Journal of the INSTITUTION OF PRODUCTION ENGINEERS

Vol. XXI No. 10

OCTOBER, 1942

CONTENTS

Published Monthly by the Institution of Production Engineers, 36, Portman Square, London, W.1. Telephone : Welbeck 2233.

Price 5/-.

Y
A

G
G
S

S SALES
DEPOTS
T THE

X HOUSE
2

—
da
kn

wh
fo
by
yo

W

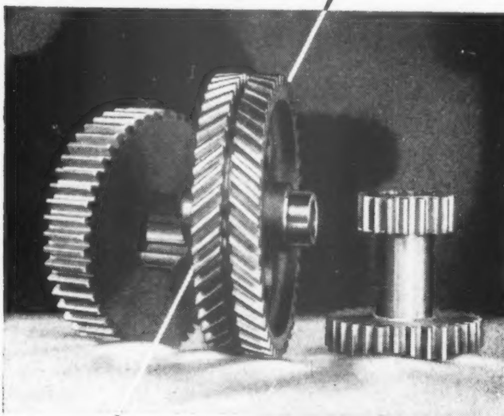
★


CLEAR, ACCURATE GRADUATIONS
An Outstanding Feature of All
N.S.F. PRECISION MEASURING INSTRUMENTS
Height Gauges
Available in two sizes with measuring range of 10 in. or 18 in. Both sizes can be equipped with depth attachments for measuring inside bores etc. The 10 in. gauge is available with either English or Metric scale. A combined English/Metric gauge can also be supplied.
Vernier Calipers
Available with measuring range of 9 in. or 25 cm. Hardened and ground jaws for measuring inside dimensions from ·300 in.
Readings by Vernier on the 10 in. and 18 in. Height Gauges and Vernier Calipers are to 0·001 in. Metric readings by Vernier are to 1/50 mm.
N.P.L. Certificate Where Required
Southern Agents
STEDALL
MACHINE TOOL CO.
145-147 St. John St., Clerkenwell, London, E.C.1.
PHONE
BRITISH N.S.F. CO. LTD.
41-43 WESTMINSTER BRIDGE RD., LONDON, S.E.1.
Northern Agents
MITCHELL FOX & Co. Ltd.
89, Meadow Lane, LEEDS, 11.
PHONE
23158-24019

BRITISH-PETERMANN
Pinion & Gear Cutting machines
BENCH AND FLOOR TYPES
TWO SIZES
Model No. 1 | With Maga. | Without Maga.
Max. dia. | .250" | .500"
Max. lgth. | .400" | .400"
Model No. 2 | With Maga. | Without Maga.
Max. dia. | 1.00" | 3.15"
Max. lgth. | 1.58" | 1.58"
Full particulars on request
CHARLES CHURCHILL & CO. LTD.
COVENTRY ROAD, SOUTH YARDLEY
BIRMINGHAM
TELEPHONE : ACOCKS GREEN 2281


NAMCO
DIEHEADS
BURTON GRIFFITHS & CO. LTD.
SPARKBROOK :: BIRMINGHAM.

Every Gear



a Masterpiece of Accurate Production

Just a Reminder

The MAXICUT Gear Shaper has a 3-BEARING Cutter Spindle, thus ensuring exceptional rigidity. This feature is exclusive to the MAXICUT and is of great value in obtaining accurate high speed operation.

when cut on a

MAXICUT

high speed

GEAR SHAPER

Ask for Catalogue DBC 168

DRUMMOND (SALES) LIMITED — BIRMINGHAM

MAXICUT GEAR SHAPERS FOR HIGH PRODUCTION OF *Accurate Gears*

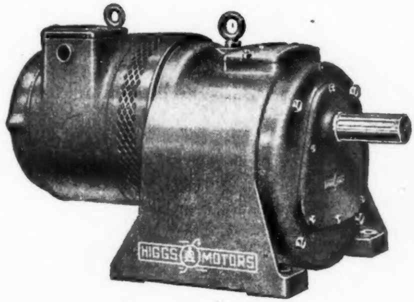
Before orders can be accepted Purchase Certificates must be obtained from the Machine Tool Control and the delivery period will be determined by this Control.

TRADE MARK

HIGGS MOTORS LTD.

GOVERNING DIRECTOR WALTER F. HIGGS M.I.E.E.

BIRMINGHAM. 6 ENGLAND

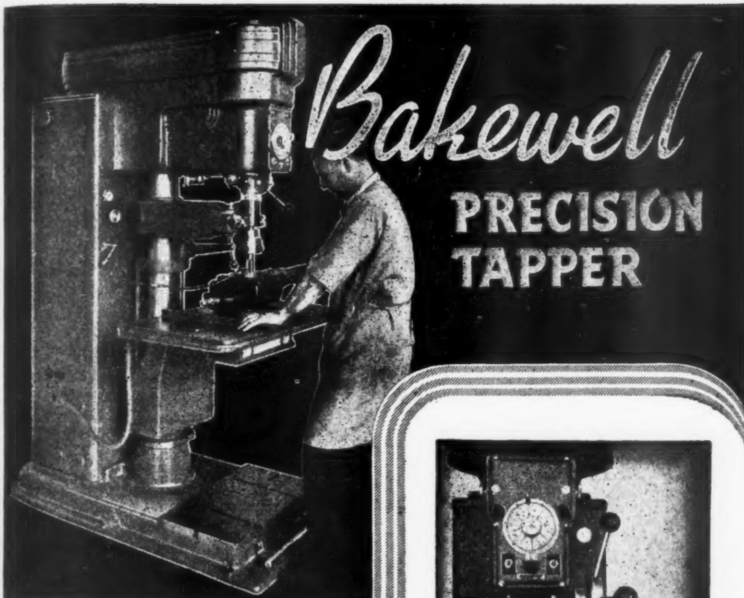


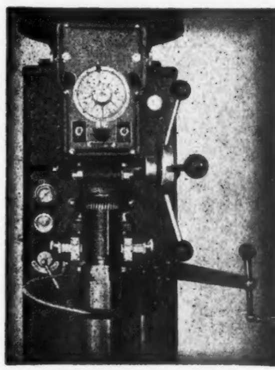
SLOW BUT SURE

During these times when strenuous effort is being made to accelerate the tempo of industry it may hardly seem relevant to record the merits of a machine which does its work at a slower than usual pace.

Nevertheless HIGGS GEARED UNITS are making a valuable contribution to our cause and for most slow speed drives they perform with unparalleled efficiency and economy.

BIRMINGHAM, BRISTOL, DUNDEE, GLASGOW, LONDON, MANCHESTER, NOTTINGHAM
PETERBOROUGH, SHEFFIELD

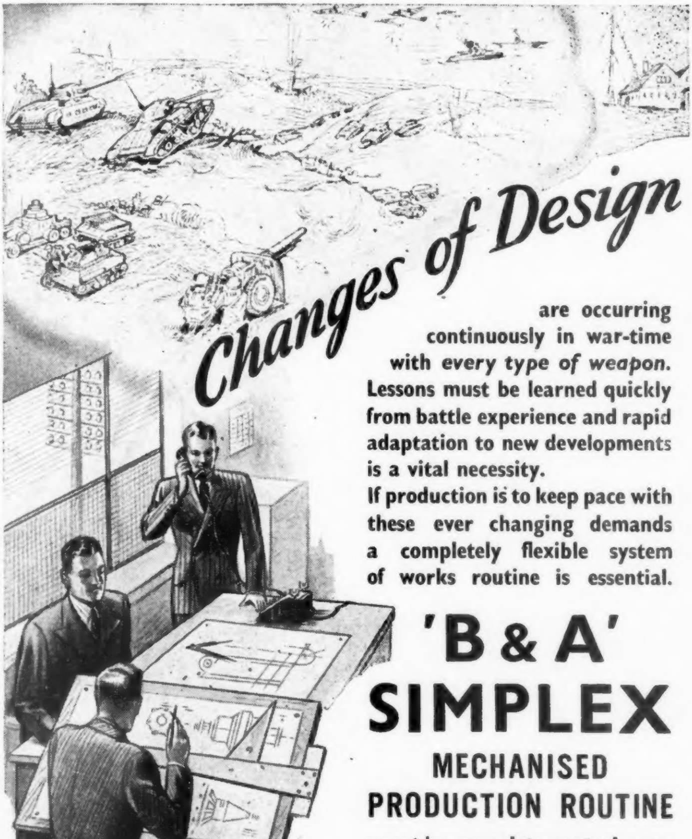

Bakewell
PRECISION
TAPPER



INDEX TO ADVERTISEMENTS

As a war-time measure the advertisement section of this Journal is now published in two editions, A and B. Advertisers' announcements only appear in one edition each month, advertisements in edition A alternating with those in edition B the following month. This Index gives the page number and edition in which the advertisements appear for the current month.

The fact that goods made of raw materials in short supply owing to war conditions are advertised in "The Journal" should not be taken as an indication that they are necessarily available for export.



INSTITUTION NOTES

October, 1942

Fixtures.

October 30—Manchester Section. Lecture by Dr. Schlesinger, on "Surface Finish," at The Mechanics' Institute, Prince Albert Street, Crewe, at 7-15 p.m.

October 30—North Eastern Section. Lecture by F. H. Bates, Esq., A.M.I.P.E., on "Tungsten Carbide Cutting Tool Application," at The County Hotel, Newcastle at 6-30 p.m.

October 31—Manchester Section. Lecture by Dr. Schlesinger on "Surface Finish," at University of Liverpool (Arts Building) Brownlow Hill, Clock Tower Entrance, Liverpool, at 2-30 p.m.

November 4—Sheffield Section. Lecture by A. E. Shorter, Esq., M.B.E., M.I.Mech.E. on "Surface Hardening," at the Royal Victoria Hotel, Sheffield, at 6-30 p.m.

November 14—Yorkshire Section. A Discussion will be opened by J. D. Scaife, Esq., M.I.Mech.E., M.I.P.E., and a Graduate on "The Young Production Engineer, His Training and his Prospects," at the Great Northern Hotel, Leeds, at 2-30 p.m.

Twenty-First Birthday Celebration Meeting.

Between five hundred and six hundred members and visitors attended the Twenty-First Birthday Celebration Meeting, held in conjunction with the Annual General Meeting, on Friday, October 23, 1942, in the large hall of the Institution of Civil Engineers, London. The occasion was an outstandingly successful one.

Mr. Oliver Lyttleton, M.P., Minister of Production, was the guest of honour, and his important speech was followed with close attention by his large audience. Mr. G. E. Bailey, who first occupied the chair, handed over the Presidency of the Institution to Sir Ernest Lemon during the course of the proceedings. In addition to speeches from Mr. Bailey and Sir Ernest, there were speeches from three other members who have occupied the Presidential Chair—Sir Alfred Herbert ("Herbert No. 1," as Mr. Puckey called him), Lord Sempill (now Deputy-President), and Mr. Tom Thornycroft. Short speeches were also made by Mr. H. A. Hartley (incoming Chairman of Council), Mr. N. V. Kipping (retiring Chairman of Council), Mr. W. Puckey (Member of Council), Mr. R. Kirchner (Member of Council and President of the London Section), and Mr. J. T. Kenworthy (Member of Council, who was elected a member of the Institution in 1921, the year of its foundation.)

The attendance included a large number of Members of Council, foundation-year Members (including Messrs. J. D. Scaife, Past-President; J. H. Bingham and J. G. Young, Past-Chairmen of Council; A. T. Davey, first Hon. General Secretary; R. Hutchings, T. Sykes, C. F. Hammond, R. D. Wooster, and others). There were also many distinguished visitors, amongst whom were many Managing Directors of Affiliated Firms, Presidents of kindred Institutions, Government officials and old friends of the Institution. The list is too long to publish in these *Notes*, so mention can be made of a few only, such as Mr. C. J. Bartlett, Sir Frank Gill, Sir Percy Mills, Sir A. W. Garrett, Sir Amos Ayre, Mr. P. Good, Mr. J. C. Blair, Mr. C. B. Colston, Mr. E. S. Bing, Mr. O. V. Guy, Mr. J. Gray, Col. H. B. Sankey, Mr. J. G. Lang, and Captain de Chair, M.P.

During the meeting Mr. B. C. Jenkins was presented with the Institution Medal for the best paper by a Member ("The Utilization and Training of Labour").

The President and Council entertained Mr. Lyttleton to luncheon at the Mayfair Hotel prior to the gathering at Great George Street, where tea was served at the conclusion of the proceedings. A report of the speeches will appear in an early issue of *The Journal*.

Substitute Graduateship Examination.

The following candidates have recently passed examinations held in substitution for the normal Graduateship Examination: S. Bateman, H. F. Box, S. F. Cutmore, E. W. Harris, J. Y. Ireland, H. E. Jones, H. Kohn, T. W. Leech, A. Webster, H. Wood.

Obituary.

We regret to have to record the deaths of Mr. J. W. Rice, a foundation member of the Institution, and of Mr. R. W. Guilliford, (*Graduate*).

TURBINE BLADE PRODUCTION

Paper presented to the Institution, North Eastern Section, by J. Henderson, A.M.I.P.E.

SOME of the members here tonight have heard it said or at any rate inferred that the science of production engineering is only applicable to a very limited extent so far as the normal peace-time heavy industries of the North East are concerned. Persons who make such statements are obsessed with the idea that production engineering only applies to mass production, nothing could be further from the truth.

With this in mind I will purposely during the course of this paper make reference to 'old methods' with a view to demonstrating how the application of the science of production engineering has benefitted turbine blade manufacture.

It may be argued that turbine blade manufacture is not heavy engineering, I agree it is not in itself, but blading is the heart of the turbine, whether it is driving a generator in a power station or a warship into battle.

In the time available it is impossible to give a comprehensive paper on turbine blade production, and for this reason I have only selected a few problems which I thought might be of more general interest. In normal times I would have been able to show you a series of slides which would have conveyed in a very much more interesting way what I am about to try and describe to you in words with the aid of a few sketches.

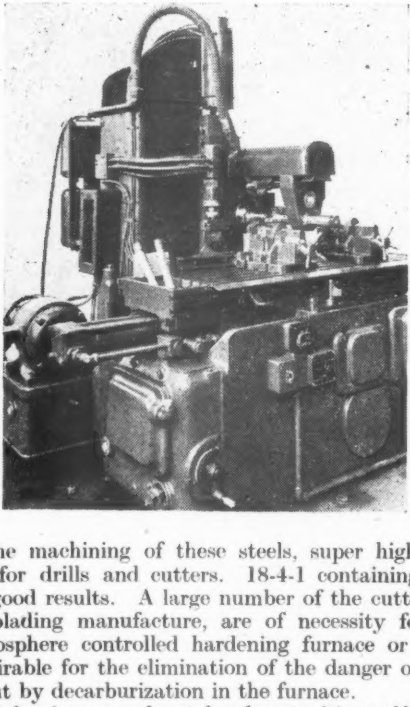
Materials.

The last 20 years have seen vital changes (so far as the production engineer is concerned) in the materials employed for the manufacture of steam turbine blading. Twenty years ago, a large percentage of the blading manufactured was of copper, manganese copper, phosphor bronze, 70/30 brass and mild steel. The packing sections, gland strip and shrouding were also made from one of these materials and brazing, where it was called for, was carried out with silver solder. Cutters used for machining the blading were of high carbon steel, and rolls for rolling the blading were of case hardened steel, steel, high carbon steel, or chilled cast iron. Twenty years of progress in the utilisation of steam for power generation, has altered all this. Reaction blading is now made on a large scale from stainless iron, (i.e. a steel containing about 0.1% carbon and about 13% chromium) packing sections from mild steel and shrouding from

monel metal. The brazing is carried out with 70/30 brass. These changes in material now demand a higher grade of steel for tools used in blading manufacture and 18-4-1 H.S.S. is essential for cutters, drills, etc.

Austenitic steels are now being used more and more for turbine blading, for example Hecla A.T.V. Weldanka and Stayblade. The former being used almost exclusively in the manufacture of astern impulse blading for marine work.

The rolling and machining of austenitic steels is a very much different proposition from that of rolling and machining stainless

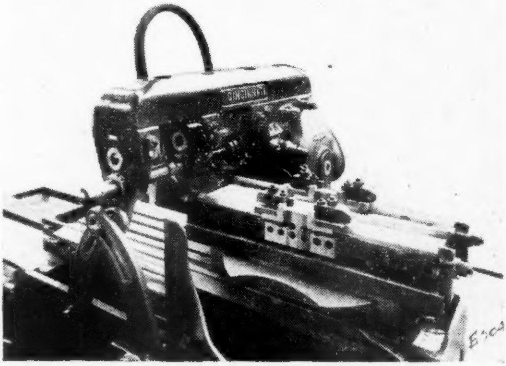


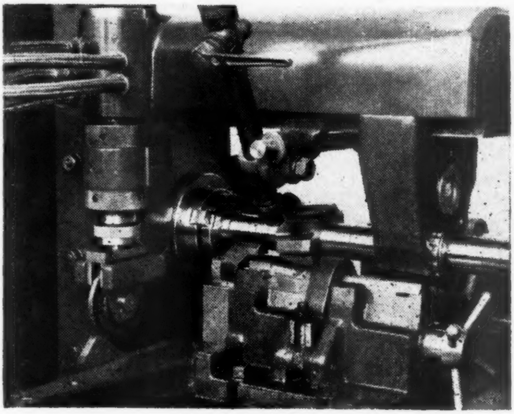
iron. For the machining of these steels, super high speed steel is desirable for drills and cutters. 18-4-1 containing 5% cobalt, giving very good results. A large number of the cutters employed in impulse blading manufacture, are of necessity form relieved, and an atmosphere controlled hardening furnace or salt bath is therefore desirable for the elimination of the danger of a soft skim brought about by decarburization in the furnace.

Rolling stainless iron monel metal and austenitic steel has demanded something better than case hardened, or high carbon steel rolls, and nickel-chrome rolls are now used extensively for cold rolling, chilled cast iron is still used for hot rolling on mild steel packing section.

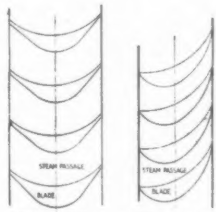
The Rolling of Blading Material.

The stainless iron material from which reaction turbine blading is rolled, is in the form of flat rectangular strips of varying cross section to suit the areas of the respective blade profiles to be produced. The length of the stock is from three feet to four feet which is dictated by the length of finished blade strip which can be handled on the drawbenches during the cutting and straightening operations, this being in the region of ten feet to twelve feet. The question





of handling such a difficult profile of so small an area during the latter stages of rolling also prohibits the use of longer lengths. At the same time, it must be realised that the longer the length of each strip, the less is the percentage of scrap due to tag ends, (i.e. the leading end of the strip which is deformed by the initial bite of the rolls, and damaged by the grips on the drawbench). It is essential that the handing of the rolls will be such that the leading end of the strip is the end to be gripped by the drawbench grips during straightening and cutting to width, or the scrap will be unnecessarily doubled.



1.

It is worthy of note that a reaction blade profile is a very difficult section from a rolling standpoint because of the very great differential extension which tends to occur. As a result of this differential extension, there is a tendency for the strip to elongate more or less in proportion to the percentage reduction and curve to accommodate this differential extension with the thin edge of the profile as the outer radius. This tendency to curve is resisted by very strong guides which bring the strip out of the mill almost straight.

In all cases, the rolls are designed with the top roll slightly larger than the bottom one (about $\frac{1}{8}$ in. on diameter) so that the material will tend to bend downwards when it leaves the rolls. This is desirable because, if the rolls were made equal in diameter the strip would theoretically issue straight, but in practice would issue either up or down. It is rather difficult to provide stripper gear to operate from the top, and, further, the mill operator would be working blind, and it is accordingly arranged that the strip will tend to issue downwards. Good sturdy strippers can then be provided and the forces are acting down on to the bed of the rolling mill. The stripper is a hardened steel tongue shaped to fit the bottom or "female" roll profile and tapered on the underside to fit snugly down close to the roll to prevent the issuing strip from catching underneath it. The function of the stripper is to pick the strip out of the bottom roll. Both the stripper and the guides on finishing operations are faced with brass to prevent damage to the highly polished blade strip. The working surfaces of the

rolls are highly polished, as the surface produced on the work is entirely dependent on the condition of the roll surface. One of the difficulties experienced in the cold rolling of stainless iron, is its tendency to what is known as "pick up." That is, a small patch on the surface of the strip firmly adheres to the roll and is torn out. This would produce a rough patch at every revolution of the roll on successive blade strips and must therefore be carefully rubbed off with a piece of hard wood and fine abrasive.

The modern procedure in preparing nickel-chrome rolls, is to rough turn the roll in the annealed condition and then oil-harden. The roll is then mounted on the mill spindle on which it is to be used and finished turned in the hard condition using form tools of silver steel.

This procedure eliminates the effects of distortion due to hardening. Fig. 2 shows a typical pair of rolls used for producing stainless iron blading. You will notice that the rolls close at the thick edge of the strip, but at the thin edge the bottom roll is cleared away to allow the surplus material to form a "fin" or "flash." One of the great aims in roll design is to eliminate "fins," but in practise it is found desirable to leave a very slight excess of material or otherwise variation in the rolling will cause some of the strip to be narrow

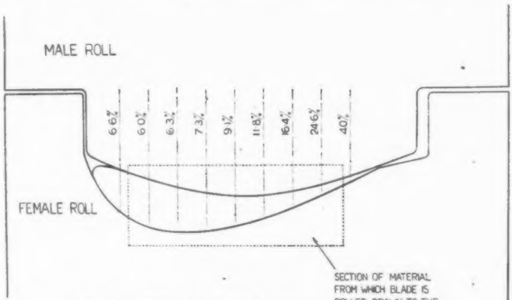


Fig. 2. — TYPICAL PAIR OF ROLLS USED FOR ROLLING REACTION BLADING (THE FIGURES ON THE VERTICAL CHAIN-DOTTED LINES REPRESENT THE PERCENTAGE REDUCTION AT THESE POINTS IN THE LAST ROLLING)

and consequently rejected. The "fin" or "flash" must be removed at a later operation, and in the case of blading, it is done by drawing the blade strip through a brass block on a drawbench. The block is made in halves and machined so that when the two halves are together an opening remains the shape of the blade profile. A tool is secured to the face of the block, and this cuts the strip to width. The sharp edge left by the tool has to be dressed later by filing. Previous to the introduction of this "cutting" operation

as it is termed, the whole of the fin, which varies from zero to $^1/_{16}$ in. in width, was removed by hand filing.

In the early days of the manufacture of S.I. blading, the rectangular strip was hot rolled to within approximately .3 in.—.4 in. of the finished blade profile, and then annealed and pickled, final rolling being carried out cold. This procedure gave a surface finish on the blade strip very inferior to that obtained by the methods now employed, and as you are all probably aware, the resistance to corrosion of stainless iron depends to a large extent on a good surface.

Stainless iron reaction blading is now cold rolled entirely from the bar stock to the finished blade profile, except in the case of the largest sizes which are given one hot rolling to break them down roughly to shape, and to avoid the excessive number of cold rollings which would otherwise be required. The more cold work which can be done on the material, the more nearly it will approach a " mirror " finish, because each successive rolling rolls out, and reduces in size the surface imperfections in the stainless iron bar, as it is obtained from the steel works. The surface imperfections referred to only amounts to a fine pitting caused by the pickling operation for scale removal after hot rolling, and any marks due to imperfections in the roll surface.

From the foregoing remarks, the reason for the improved surface finish when cold rolling is employed, will be apparent. In actual practice the evils due to hot rolling nearly to size, are worse than might be imagined, for the following reasons:

(1) Scale is rolled into the surface of the strip and when this is removed by pickling, worse surface defects are produced than are present in the case of the virgin bar.

(2) Any carbonaceous matter (i.e. dirt or oil), present on the surface of the hot rolled strip when it is put into the annealing furnace, causes carburisation of local patches, and these patches, with their higher carbon content, are more easily attacked by the pickle than the parent metal, with the result that local pitting occurs.

With present day methods (i.e. cold rolling from the bar stock), annealing is only carried out in the larger sizes of blade where the amount of cold work would be so great as to work harden the material to the extent of a fracture. On all the smaller sizes of blade, annealing in the strip form is not necessary, because, as will be seen later, the complete blade segments into which the strip is built, are annealed as a whole after brazing.

Because of the fact that any foreign matter on the surface of the strip adversely effects the surface when annealing, all strip is previously degreased in a degreasing tank employing Thrichlorethylene vapour.

The cold rolling of blade strip is carried out on 8 in. or 12 in. rolling mills, dependent on the size of the strip, and two rolls only are employed, a male and a female, that is, there are no backing up rolls. During rolling the rolls are flooded continuously with a stream of soluble oil and water. It is worthy of note that the same supply of coolant is used to cool the roll neck bearings. In the past gunmetal bearings were used and carbon steel roll spindles, lubrication being effected by the mill operator applying heavy oil with a brush on to the exposed top half of the bottom journal and between the halves of the top roll neck bearing.

The bearing brasses had a life of only a few months, and there were repeated stoppages due to the roll necks and bearings heating excessively. All this has now changed, however, and the roll neck bearings are of bakelized linen, the bearing being so cut out of the pressed material that the laminae is at right angles to the roll axis. It is worthy of mention that when bakelite bearings are used the roll spindles must be of Nitralloy. The results obtained are phenomenal, bearings last for a number of years instead of months, and the longer the journals run, the more highly polished do they become and wear is negligible.

Hot Rolling of Mild Steel Packing Section.

The methods employed in the manufacture of mild steel packing section have been improved as much as, if not more than those employed in the manufacture of blading.

In the days of copper and brass packing section, the rectangular bar stock was generally just tapered by rolling, and then given three draws on a drawbench; through roughing, semi-finish and finishing dies, the first drawings had the effect of simply bending the wedge shape produced by rolling more or less into the form of a blade packing, and subsequent drawings finished the profile and brought up the sharp edges. It was then a very simple matter to control the flow of the metal to the sharp corners of the profile by altering the flare of the die opening, but with steel it is a totally different proposition.

The method used for brass was not applicable owing to the very much higher strength of steel. The number of draws and intermediate annealing would have been out of the question. The early method of producing steel packing section, therefore, was to give the round or rectangular bar stock three or four hot rollings through suitably shaped passes, the profile of the passes progressing gradually from the stock shape to the finished form. A heat of bars was fed into the furnace and brought up to temperature, the bars were then fed through the first pass in the rolls and allowed to cool on the floor. The entire quantity to be rolled was treated in this way and then re-heated and rolled through the second

pass, and this procedure was repeated for the third and fourth passes. In many cases a flash formed in the rolling had to be ground off between passes. After hot rolling the section was annealed and pickled, and then given two or three draws on a drawbench depending on the size of the section.

A few years ago the production of steel packing section became a " bottle-neck." A careful analysis was made of the methods employed, and ways of improving them were considered with the result that production was considerably increased. The method then evolved is as follows and is identical to that used to-day.

Instead of employing four passes in the rolls only two are used, and it is interesting to note that in the old method the passes in the rolls were turned with half of the profile in the top roll and half in the bottom, the junction being across the chord of the section, the only change from pass to pass being in the shape. In the new method the bar stock is broken down in a channel shaped pass, the top roll having a male profile which locks between the sides of the bottom roll pass. The finishing pass for hot rolling is rather similar to the type used in the old method, but instead of the profiles being cut in the rolls so that the chord of the section is horizontal it is cut so that the points on the section profile which correspond to the chord of the blade are horizontal.

With the new roll pass shapes, continuous rolling is employed, i.e. the bar stock is heated in a furnace and then rolled through the roughing and finishing pass without intermediate re-heating. Rolling speeds are doubled and the H.P. of the mill driving motors increased about $2\frac{1}{2}$ times. By this method the temperature is maintained during rolling by the heat generated in the deformation of the steel, and the heat loss due to radiation, and conduction to the rolls reduced at the same time by virtue of the increased speed of rolling.

After hot rolling, the strip is fully annealed and pickled and then instead of being drawn as in the case of the old method, it is cold rolled through nickel-chrome steel finishing rolls of a special design. The rolls are locked together to give accurate positioning and the enormous axial thrust produced as a result of the unsymmetrical section being worked upon, is taken on two thrust faces provided in the design of the pass.

Impulse Blading.

The most commonly used materials for impulse blading at the present time are stainless iron for power station work and Hecla A.T.V. for marine work. Monel metal, phosphor bronze, manganese copper and pure copper are also employed to a limited extent. The rolled section is in the form of a combined blade and packing section to form the blade profile.

Impulse blading is rolled from rectangular bar stock in a series of passes designed to bring up the sharp edges of the combined section which will ultimately be inlet and outlet edges of the blade which must of necessity be well finished.

There is one very important point in connection with the roll shape which has a very big bearing on subsequent machining methods and that is in order that the section will strip from the deep pass in the bottom roll, the sides must be tapered. This means that the sides of the combined section as rolled, are not reliable as a location for subsequent machining operations and it is usual therefore to locate from the back of the profile.

Copper, manganese copper and phosphor bronze are rolled very nearly to the finished form and are then given a final drawing.

Integral Reaction Blades.

An integral blade is one in which the blade and root portion are produced from a solid billet of steel. With the high blade tip velocities now employed at the exhaust end of the turbine the blade root stresses are high and it is usual on the larger machines to fit integral blades instead of short brazed group type for the last few rows of low pressure blading.

The method adopted by the firm with which I am connected in producing integral blades is as follows :—

Billets for rolling are prepared in two ways : (a) by pressing, (b) by milling. Where the blades are of expensive material, such as stainless iron, the billets are pressed from bar stock. This is carried out in two different ways. The first is to cut to length, bar stock of the section required to produce the blade root, and then reduce by pressing in a die the portion of the billet which will ultimately form the blade. The second method is to cut to length bar stock of the section required for rolling the blade, and upset this for a portion of its length to the section required to produce the root.

The former method is employed for the smaller blades and the upsetting method for the larger type.

In cases where the blades are to be produced from Mild Steel or are made from stainless iron, Weldanka or Stayblade, but are too large to justify pressing, bearing in mind the relatively small numbers required then bar stock of the root section is slab milled down on each edge to form the section required from which to roll the blade. It will be appreciated that pressing makes for a considerable saving in material.

Integral reaction blades are rolled in what is known as a " Gap Roll," that is a pair of rolls in which a portion of the circumference of both the top and bottom roll profile is cut away to clear the portion of the billet which will form the blade root .

Tapered Integral Blades.

Further increases in blade tip speed have resulted in the necessity for producing large blades up to 3 in. chord width tapered in section from the root to a point about $^2/_3$ up the blade, and then parallel but of very much reduced section for the remaining third to the tip. These blades are used in the last row, or two rows of blades at the exhaust end.

The tapering was, until very recently, carried out by profile milling a rolled blade of uniform section in a jig. This method has now been superseded by rolling the taper on the blade and thus eliminating the taper milling operation and the necessity for expensive form relieved milling cutters.

This method is proving quite successful, and effects a saving in material as a shorter billet can be employed.

The Machining of Turbine Blading.

The methods employed in the machining of Turbine Blading have been improved as much, if not more, than the advances which have been made on the rolling processes during the last twenty years.

The improvements have largely been brought about by the development of the manufacturing type of milling machine and a better understanding of the application of jigs with a view to eliminating, or at least reducing loading time.

Two methods have been employed in the elimination of loading time :

(1) The use of two-way table cycle manufacturing milling machines.
(2) The use of index bases on one way table cycle machines.

There is one interesting feature of a two-way cycle machine worthy of mention, and that is, the work piece in one jig is milled by the orthodox method of milling, while the work piece in the other jig is down cut milled. As a result of this two-way cycle milling machines when they are to be used for slab milling or form milling, must be fitted with some form of backlash eliminator on the table traversing screw.

The difference between orthodox and down cut milling is chiefly in the direction of the resultant thrust from the cut and the clearance and rake angles required on the cutter. In the case of orthodox milling, the resultant thrust is composed of a component tending to pull the work piece out of the jig (i.e. vertically upwards) and a component parallel to the surface of the table in the opposite direction to the feed. When downcut milling the resultant thrust can be resolved into a vertical component, thrusting the work piece down on to the machine table and a horizontal component in the same direction as the feed. In my opinion there is a definite

future for down cut milling on turbine blading, because the work piece is very thin and by nature very difficult to hold, as a result of which a percentage of scrap is produced due to blades being pulled out of the jigs when orthodox milling is employed.

When discussing down cut operations, there is one other interesting feature. I had the idea that a hydraulically fed table operated on the differential pressure system should be free from backlash and proceeded to carry out tests on down cut milling. The results, however, were not good and, although the cutter did not break, there were definite signs of the work pulling in. It would appear that either the hydraulic oil used is capable of being compressed to a very slight extent or that minute air bubbles in the oil allow of a small amount of volume compression.

This experiment was carried out on a Cincinnati 3-36 hydromatic fitted with a servo gear, and it may be that the tendency to drag in was aggravated by a certain amount of what might be termed "hunting" on the pilot valve. When a one-way table cycle is employed two jigs are mounted on an index base and while the jig on one end of the index base is under the cutter, the jig on the other end is being loaded, and vice versa.

Another machine tool development which has considerably increased and facilitated production on the manufacture of impulse turbine blading, is the servo gear fitted to the Cincinnati hydromatic milling machines. This servo gear is made use of in the milling of the profile and reinforcement on the back of impulse turbine blades.

Conventional milling is employed, but in my opinion this is a case for down cut milling if a means can be devised for making the hydraulic table feed completely free from any tendency to draw in under the action of the cut.

Operations in the Production of Impulse Turbine Blade from Hecla A.T.V. Material.

The strips of rolled material, as received from the rolling mills, are cut to length on a machine employing 12 in. dia. by $^3/_{32}$ in. wide abrasive discs, this is a very much quicker and cheaper method than sawing the material under consideration.

Up to a few years, ago no attempt was made to machine the sides or steam face of the impulse blade combined section profile as received from the rolling mills. This resulted in great difficulties in the machining, due to lack of any reasonably accurate surface as a location for the first operation, which was to mill the form of the back of the blade. This resulted in an unnecessarily large percentage of scrap, or work which had to be corrected, further, a considerable amount of hand fitting had to be done in filing the blades to width, and on the root portion of the blade a

relatively large amount of metal had to be removed in the serrating operation by an expensive form relieved cutter.

The reason for the absence of a reliable surface on the sides of the section, as rolled, has been explained.

Present day methods, however, have eliminated all of these difficulties, as in the first operation the tapered sides of the rolled section are straddle milled parallel and to width and at the same time the steam face is cleaned up by means of a form relieved convex cutter mounted between inserted tooth side and face mills **Fig. 3.** The blades are milled two at a time side by side, two sets of cutters being mounted in a gang on the arbor. In the case of the smaller

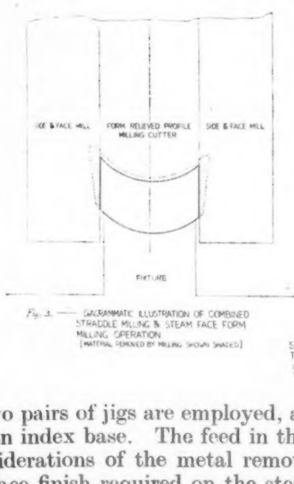


Fig. 3. — DIAGRAMMATIC ILLUSTRATION OF COMBINED STRADDLE MILLING & STEAM FACE FORM MILLING OPERATION (MATERIAL REMOVED BY MILLING SHOWN SHADED)

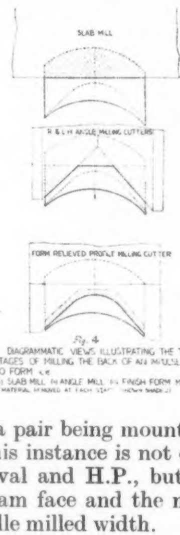


Fig. 4
DIAGRAMMATIC VIEWS ILLUSTRATING THE THREE STAGES OF MILLING THE BACK OF AN IMPULSE BLADE TO FORM i.e. (i) SLAB MILL (ii) ANGLE MILL (iii) FINISH FORM MILL (MATERIAL REMOVED AT EACH STAGE SHOWN SHADED)

sizes, two pairs of jigs are employed, a pair being mounted on each end of an index base. The feed in this instance is not determined by considerations of the metal removal and H.P., but rather by the surface finish required on the steam face and the maintaining of an accurate dimension on the straddle milled width.

Great accuracy is demanded on the width because it is from these surfaces that all the succeeding jig locations are made and extreme accuracy is therefore essential, if blades lying at the correct angle in the groove are to be obtained and the designed opening coefficient realised.

Straddle and steam face form milling is another operation from which I consider benefit could be derived by adopting down cut milling instead of conventional milling. The reason for this being that on long slender blades, which by virtue of the operation to be performed, can only be held at the ends, the straddle mills to a great extent and the convex form mill to a lesser extent lift the

blade off its seat in the jig when they are operating near the centre of the work piece, with the result that the blade is thin in the middle. Where the error becomes excessive, the straddle milling and form milling are divided into two operations with a resultant loss in production. The next operation consists of milling the form on the back of the blade.

This is carried out in two different ways. The first being to mill the back of the combined section in a longitudinal direction and the second, to mill away the material transverse to the blade length by means of a slab mill, or in some cases a form relieved cutter.

Considering the first method as applied to the larger blades, the material is cut into single blade lengths and then form milled in three operations :—

(a) Slab mill off as much material as possible.

(b) Angle mill the straight sides of the form to the correct angle.

(c) Finish mill with an accurate form relieved cutter.

These operations are all carried out on 3-36 Cincinnati hydromatic plain milling machines, two work pieces being mounted one at each end of an index base. It is worthy of note that the

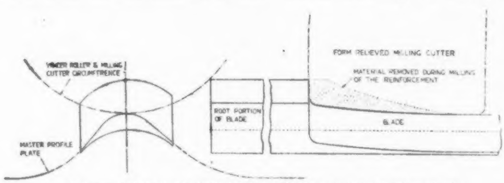


Fig. 5. — DIAGRAMMATIC VIEW ILLUSTRATING THE OPERATION OF MILLING THE REINFORCEMENT

hydraulic feed system gives a definite increase in cutter life over screw feed machines when performing this particular operation, and working on such difficult material as Hecla A.T.V. The reason being that the feed is not uniform, but consists of a minute rapid advance as a tooth is starting to sheer its chip and then slow feed as the tooth is continuing uniformly to cut the material, as soon as the tooth in question leaves the work, the work table surges forward again. The ribbing action of the cutting edges of the teeth before commencing to shear a chip, which is an inherent feature of orthodox milling on screw feed machines being thus considerably reduced.

On all except the smallest sizes of impulse blades used in marine work, the blade profile is not uniform throughout the length of the blade, a gradual reinforcement being provided at the root. This reinforcement is milled in a rough and finish cut by passing a form

relieved cutter transversely over the back of the blade on a 3-36 Cincinnati milling machine equipped with servo control. Fig. 5. Two fixtures are mounted on the machine table, and two form plates are mounted on the side of the fixtures in correct relation to the locating surfaces on the fixtures. One of the form plates is about .02 in. lower than the other, so that the blade in the first fixture is roughed and that in the second finished. In this way, one finished work piece is obtained per table cycle, which is one way only and conventional milling is therefore employed.

The serrating of spindle blade roots and dovetailing cylinder blade roots is carried out on machine tools designed for this specific operation only. The machine tools consists essentially of a head housing two cutter spindles, the distance between the spindle centres being capable of adjustment to fine limits. A form relieved serrating cutter is mounted on the end of each spindle and the spindles run in opposite directions. The blade is mounted in a fixture which is in turn bolted to the end of an arm which swings across the bed of the machine tool, pivotting about a centre pin which can be adjusted in a slot in the bed to give any desired radius, corresponding to the cylinder or spindle blade groove radius. The blade root is fed between the cutters in the correct axial position and the feed is by hand. The radial taper or backing off, as it is commonly called, is next milled on the blade root. This is a very simple operation carried out on a plain horizontal milling machine. The blade is located from the steam face and parallel sides in a fixture inclined at the required angle, and fed under a concave form relieved cutter having the same profile as the steam face of the blade.

Great accuracy is required in this operation if the blades are to fit close back to front when knocked up in the groove, and give the correct inlet and outlet angles and opening coefficient.

The tenon for securing the shrouding on top of the blade is next milled.

In some cases a round tenon is called for, and in others a parallel sided tenon with semi-circular ends. The circular tenon is produced by milling away the blade form by means of a hollow mill on a canting machine. This is by far the best type of tenon, from a production point of view.

The parallel sided tenons with semi-circular ends are produced by milling away the surplus blade profile in two cuts. One in line with the blade groove and the other at right angles — two side and face mills mounted on the arbor of a horizontal milling machine separated by micrometer spacers to give the correct tenon size are employed.

The blades are finally polished all over their effective length on polishing mops. The steam face is polished with a small mop having a radius equal to that of the concave face of the blades

in order that the fine scratches produced by the grains of abrasive will be in the direction of steam flow and not at right angles to it, thus reducing friction.

Operations Employed in the Manufacture of Short Brazed Group Type Reaction Blading.

The blade strip, as received from the rolling mills, is cut to length by shearing in a correctly profiled punch and die to prevent distortion of the form.

To allow for the fact that the tip of the blades must form as near as possible a cylindrical surface when built up, the cropping punches and dies are so designed that the blade is not cut at right angles to its surface, or its edge, but is inclined, the angle of inclination varying with the diameter and cone angle.

The blade packing section, as received from the rolling mills, is cut to a length equivalent to the root height plus two hundredths of an inch to allow for root milling of the segment. The sections are cut on a special single purpose cutting off machine.

This machine tool is fitted with four saws and operates on two lengths of section at once. The work is stationary and the head carrying the saws oscillates across the work. When cutting square topped sections, each saw cuts a section, that is, four sections are produced per cycle. When cutting taper topped sections, however, the first and third saw cut the angle and the second and fourth part off the section and thus two finished sections are produced per cycle. The machine is entirely automatic, the bars being fed forward against stops by means of a block pushing on the back end of the bar and traversed by a screw operating through a slipping clutch. The sections are gripped while sawing by solenoid operated vices which release as soon as the feed forward motion is initiated.

A small edition of this machine tool, but without inclineable heads for angled sections is employed for the cutting of the smaller sections and locking strip.

The bottom end of the packing sections are now notched for welding. This operation is performed on two-way table cycle milling machines equipped with fixtures which grip two sections side by side.

The packing sections are next what is known as " backed off " that is, they are milled to the correct taper to suit the radial positioning of the blades.

This operation is also performed on two-way cycle milling machines and two sections are gripped side by side in a special fixture, two form relieved cutters being mounted on the arbor. The centre portion of the jig which carries the sections is mounted in trunnions in the fixture body so that it can be tilted to any radial angle,

thus making the jig universal, all that is required is to change the gripping inserts to suit the sections to be operated upon.

This is an interesting application of downcut milling which has given every satisfaction.

At this stage it should be mentioned that ten years ago it was the practice to drill all blades and packing sections in order to enable them to be threaded on a mild steel root wire for purposes of assembly. This method was costly and slow, as a result of which the method about to be described was developed.

The number of sections required for one segment are placed in a slot in a fixture and the blades inserted between each section, pressure is then applied at right angles to the groove and in line with the groove to bring each blade and packing section closely together. There is a radius bar at the bottom of the slot in the fixture in order that the segment will build up to the correct diameter for the groove in which it is to be fitted.

In the case of end tightened blading, the shrouding is next rivetted on to the blade tenons, and any lacing wires, if required, are threaded through the holes provided in the blades. In the case of radial clearance blading one lacing wire at least is fitted.

The upper portion of the fixture in which the root of the segment is now firmly clamped is swung through 180°, being hinged at the front. The radius bar remaining in the base of the fixture. The underside of the segment root thus exposed can be welded at will. The clamping screws are released and the segment removed from the fixture, the run of welding along the bottom holding the blades and sections securely for the brazing operation.

The use of the correct rod is essential, because of the fact that mild steel packing sections are being welded to stainless iron blades and the weld must not crack or disintegrate in any way during brazing.

The lacing wires or shrouding, as the case may be, are now brazed to the blades by means of hand blowpipes operating on town gas and compressed air, 70/30 brass is employed, fused borax and boric acid being used as flux.

The complete segments with their shrouding or lacing wires brazed are now liquid brazed at the roots. This operation is carried out in an Ajax Wyatt electric induction furnace supplemented by gas fired crucibles for the smaller sizes of segments. For consistently sound brazing there are three factors which must be carefully controlled :—

(a) Time.
(b) Temperature.
(c) Cleanliness of the blades and sections before assembly.

The furnace chamber or crucible is filled to a suitable level with molten brass and above the brass is a layer of molten borax about ½ in. deeper than the full depth of the segment root taken across the chord. (Fig. 6).

The segment root is first immersed in the borax and heated up to brazing temperature, during which time the borax throughly cleans and prepares the surface of the metals for brazing. The segment is then lowered until the highest point of the root of just below brass level, brazing occurs almost instantaneously.

The timing of this operation is controlled by a cam driven from a synchronous motor. The segments are suspended by means of wire hooks from a carrier which is in turn coupled to the end of an

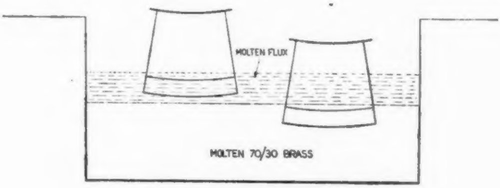


Fig. 6. — ILLUSTRATION SHOWING BLADE SEGMENT IN THE POSITIONS OCCUPIED DURING THE TWO STAGES OF LIQUID BRAZING.

arm which projects to the centre of the crucible. The arm is pivotted at a point about ²/₃ along its length and the lever end away from the furnace bears on the surface of the aforementioned cam. The height of the projections on the cam control the movement of the segments in the crucible as regards height and the length of the projections circumferentially control the time. The cams are easily changed for different sizes of segments. It is interesting that the times for the different sizes of blades were initially determined by actually brazing segments and then breaking open the roots in order to determine what sort of a bond had taken place between the blades and sections. A few years ago a rather ingenious method was developed for obtaining a comparison between the quality of the brazing of segment roots by passing a heavy current through the root and measuring the millivolts drop across it. Any segments having a higher potential difference across the ends than the average value are drop tested across each junction between blade and section and the point at which the brazing is faulty or cracked is easily located. The great advantage derived from this development is that faulty segments can be rejected and rebrazed before machining, as it is very much more difficult and expensive to correct them after the roots have been machined.

As regards temperature control of the brazing, this is done by inserting a pyrometer in the molten brass from time to time and maintaining the temperature between very narrow limits. Ten years ago brazing was carried out in crucibles heated by coke fires, this method was dirty, handling charges were high, there was a considerable percentage of unproductive time, scarring and cleaning the fire and replenishing with coke, and most of all temperature control was very diffcult, as it could only be done by the fan damper on the air supply. The Ajax Wyatt electric furnace and coal gas fired crucibles have been a great step forward for obvious reasons.

Cleanliness of the blades and sections before assembling into segments and brazing is essential. The blades are degreased in a Trychlorethylene degreasing plant and the sections are degreased and pickled to remove any oxide.

The molten borax on the surface of the brass must also be kept free from an excessive quantity of impurities, and for this reason it is ladled off and replaced from time to time as soon as it becomes too highly charged with iron. After brazing, the segments are boiled in a caustic soda solution to remove borax, and then annealed and lightly pickled. It is at this stage that the electric root test previously referred to is applied.

The segments are now ready to have their roots machined to suit the grooves in the cylinder or spindle as the case may be. This operation is carried out on special machine tools designed and built by the firm with which I am connected. The essential features of the design are that the segment is carried on a small machine table which is mounted at the end of a heavy cast iron arm. A pivot pin traversed along the bed of the machine by means of a screw passes through a slot in the arm and can be locked at any desired radius to suit the cylinder or spindle groove for which the blading is required. The arm is traversed through the required arc by means of a hand operated screw operating a nut which locates in a fork on the arm at the opposite end to the pivot. The cutter spindle is mounted at the end of a rigid cast iron arm which projects from the back of the machine over the table carrying the segment.

It is worthy of mention that the design of this machine is now obselete and that a machine tool has been built capable of giving 25% greater production. The machine is similar to that described above in general appearance, but a hydraulic feed and rapid traverse return have been incorporated, thus considerably reducing fatigue of the operator and unproductive time due to having to return the table by hand on the old machines. A further interesting feature of the new design is that an index base is fitted.

The sequence of operations on the root is as follows :—

(a) Mill bottom of root.

(b) Serrate outlet side.

(c) Serrate inlet side.

Root milling is carried out by means of an end mill and the segment is located from the top of the shrouding or blade tips, correct location is vital to ensure that the axial contacts of the end tightened blading will line up correctly when the segments are assembled in the turbine.

The serrating operation is carried out with a form relieved cutter, and all the serrations are milled in one cut. In my opinion, this is another operation on which considerable advantage could be gained by downcut milling, because the limiting factor for the rate of feed is not H.P. available or chip per tooth, but is determined by the maximum cutting force permissible with the very light clamping pressure which can be applied. It will be appreciated that the very nature of the work piece makes it impossible to clamp it down really solidly or the blades would be damaged.

The location for serrating is the bottom of the previously machined root.

In bringing this paper to a close, I would like to repeat that in the time available it has only been possible to run over very briefly a few points regarding turbine blade production and that very much more could be said both as regards the ground covered by the paper and also the machining of different types of blading and its associated parts, i.e. locking strip, dummy strip, etc.

In closing, I would like to express my thanks to Messrs. C. A. Parsons & Co. Ltd., for having permitted me to publish the information appearing in the paper.

Discussion

MR. SWALLOW (Chairman): I think Mr. Henderson has given us a really good lecture on this subject, and I think it will have convinced us all that it is a highly specialised technical job, and which must be the result of years of experience to get to this stage.

The process, I should suggest, is really broken up into two stages —the rolling of the material, and the machining operations, and a very expert knowledge of metallurgy must have been necessary to get to this degree of efficiency.

There is one thing I would like to say about these turbine blades— I think they are a designer's delight. They cannot have been anything else, and the designers must have put some of these radii in just to make it difficult.

There is one thing I would like to ask Mr. Henderson—I am not quite clear as to how the back of an impulse blade is formed on the Cincinnati Hydromatic Milling Machine. Would he please run over this.

MR. HENDERSON : The blade portion of the combined section is milled longitudinally as far along towards the root as the cutter radius will permit, and the neck and reinforcement are then finished by milling transversely, except in the small sizes, in which case the blade form is produced entirely by milling transversely out of the solid.

MR. GIBSON : What inspection methods are used for checking up the machined surfaces?

MR. HENDERSON : The blade profile is checked by means of plate gauges, and as the inlet and outlet angles of the blade must be correct when the blade is in the groove, a further check is made to determine the angular relation between the inlet and outlet faces of the back of the blade and the serrating. This is done by inserting the blade in a master groove and applying a protractor. The blade height, root height and tenon height are all checked by means of female plate gauges. To ensure that the serrations or dovetail on the root will be good a fit in the cylinder or spindle groove, a special adjustable female serrating gauge is applied. The reinforcement is checked by means of a male plate gauge.

The surface of the blades must be well finished to reduce friction, particularly the steam face which is polished in the direction of steam flow.

MR. BATTY : Could you tell us how you grind your milling cutters to the correct shape, and how you sharpen them, and how you determine that they are the correct shape, because you told us that all forms have to be machined to very precise limits. I would like to know how you do it.

MR. HENDERSON : A form tool is made from the blade masterpiece and this tool is used in the relieving lathe. The cutter roughly turned to form and gashed, first rough relieved by using an ordinary narrow round-nosed tool and then finish relieved with the aforementioned accurate form tool.

The cutter used for milling the reinforcement is form relieved because of the complicated shape of the reinforcement, which consists of a small radius at the top of the root, joined tangentially by a large radius into the straight blade form.

This cutter, which is spirally gashed, and end cutting, is form relieved by using a round nosed tool in the tool holder, the form being generated by a follower the same shape as the tool, riding on a form plate, arranged at the back of the cross slide on the relieving lathe.

MR. BATTY : That is all done on the turning operation, and not in the grinding?

Mr. Henderson : Yes. No form relief grinding machine is available, and all of the cutters used have simply a turned form.

Mr. Batty : In all these forms, it would seem that the ideal way of checking them would be a projector if you had one. You could check them all in no time.

Mr. Henderson : I quite agree, and I might add that we will have a projector very soon.

Mr. Gibson : Would you have any diffciulty in establishing a standard on the drop voltage test ?

Mr. Henderson : That is a very interesting question. The absolute value of the figures means very little, they are only relative. An expansion of segments is tested and a series of figures obtained ; if these figures are reasonably consistent then the brazing is sound, but if there are one or two segments which have a voltage drop appreciably greater than the average value, then these are tested between adjacent blades and sections, which will reveal the point at which the brazing is inferior.

Mr. Silburn : If the brazing was only covered 75 %, would you be able to detect that with the voltage drop test across each pair of packing sections ?

Mr. Henderson : Only by very careful examination of the figures would it be possible to detect that a joint only had a 75 % band of brazing. Anything less than this would easily be detected.

Mr. Perks : It has been said that there are no Production Engineers in the North-East Coast, but I think Mr. Henderson has shown us that he is one. We are grateful to our president, Mr. Harriman, whose unavoidable absence to-night we very much regret, for his vision in starting this section and showing production engineers in other parts of the country that there is a nucleus of production technique in this area. Mr. Henderson, however, seems to be in somewhat of a dilemma. He has told us on the particular works subject how he prefers downcut milling, and at the same time he has told us how much he likes a hydraulic feed to the table. We cannot have both. He stated that one of the reasons for his preference for hydraulic table feed machines was the additional cutter life, and you will notice he had dwelt on the fact that he had proved that the cutter life was better with hydraulic feed.

Now, it is a well-known fact that the factories in the North East are very well provided with the latest equipment, and I should like to ask Mr. Henderson just how he compared the cutter life on the hydraulic machines with the cutter life on the screw feed machine. Was it a fixed bed-type machine or the knee and column machine and what were the conditions of these machines ?

Mr. Henderson cannot have hydraulic and down cutting milling,

since he cannot have back-lash eliminators unless he has screw feed table. These are two points I put to Mr. Henderson ; and a further point : it seems to me there are a number of people manufacturing turbine blades, and I would like to ask if it could be possible, in the North-East Coast, with the resultant economies, to manufacture all turbine blades in one shop, and would that result in additional production. Surely, in these days, we should get a considerable increase in output.

MR. HENDERSON : I would first thank Mr. Perks for his very kind remarks.

Referring to the question of hydraulic feed and screw feed milling machines, I would like to emphasise that I do not consider that there is any advantage to be gained due to downcut milling on a screw feed bed type machine as compared with orthodox milling on a hydraulic feed bed-type machine—providing the work-piece is robust and can be securely clamped.

When considering the milling of the back profile of an impulse turbine blade, however, one must bear in mind that the length of a $\frac{3}{4}$ in. wide blade may be anything up to 8 in., and the thickness at the thickest part 0.2 in., (these figures are only approximate, for purposes of comparison), coupled with the fact that much more metal is milled away than is left to form the blade ; and to make matters worse, the blade can only be clamped at the extreme ends.

The advantage to be gained by downcut milling on a screw feed machine under these conditions is, in my opinion considerable, for the reasons mentioned in the paper, and an increased cutter life will be obtained as compared with the same operation carried out on a screw feed machine employing orthodox milling.

Mr. Perks does not seem to appreciate that there is one point of similarity in the cutting conditions when orthodox milling on a hydraulic feed machine, and downcut milling on a screw feed machine, and that is abrasion between the land on the cutter teeth and the workpiece when commencing to shear a chip is almost eliminated, and therefore the generation of heat behind the cutting edge reduced : it is this abrasion which plays a part in reducing the cutter life on screw feed machines when employing orthodox milling.

The comparison of cutter life was made on both knee and column type and bed-type screw feed machines, and bed type hydraulic feed machines, but I would point out that although the bed type machine is more rigid than the knee and column type, the cutting comditions are identical if they are both employed on orthodox milling.

I agree that downcut milling cannot be carried out at present on hydraulic feed machines, but I would not go so far as to say that a machine will not be developed in time to come, which will downcut mill.

Do not misunderstand me, Mr. Perks ; there are two separate issues :—

(a) I consider that hydraulicaly-operated machine tools are to be preferred to those mechanically operated, with certain obvious exceptions, i.e. where a definite relation must be maintained between two motions, which can only be done mechanically up to the present.

(b) That downcut milling on a screw feed machine is better than orthodox milling on a hydraulic feed machine, only insofar as it eliminates the tendency for the work piece to be lifted from the fixture ; the cutter life and cutting conditions are, in my opinion, about equal.

With regard to producing all the turbine blading now made on the North-East coast, in one factory. I agree that this would make for increased production efficiency, as special purpose machine tools would be more than ever justified, in view of the increased quantities to be handled.

At the present time, however, it would hardly be wise to put all one's eggs in one basket, so to speak, particularly in such a vulnerable area, and in normal times the scheme, although ideal from a production point of view, could only be brought about by the co-operation of all the different firms concerned.

Mr. Gibson : I would like to ask Mr. Henderson if any difficulty was expereniced in getting at the most satisfactory method of removing the brazing for cleaning purposes ?

Mr. Henderson : Removal of the borax from the segments after brazing has been effected for as long as I can remember, by boiling in a caustic solution and brushing. There has never been any great difficulty in this respect.

With regard to the question of surplus brass on the blades, this must be prevented by very careful adjustment of the depth to which the segment dips into the molten brass when liquid brazing.

If this precaution is taken, there is only a fillet of brass at the point where the blades enter the packing sections, which is actually desirable.

Mr. Swallow : Coming back to downcut milling. It is too big a subject to mix in with turbine blades, but this I would like to suggest—if you are having trouble with pulling the blades out of the fixtures, could you not mill the blades round the other way employing orthodox milling ; that is, mill from the root towards the tip. ?

Mr. Henderson : The method you have outlined was used years ago when marine impulse blades were milled in a double blade length (that is, a right- and left-hand blade together), and parted later.

This method was very slow, however, as it involved feeding in to depth for every blade by raising the knee of the milling machine. This was slow, tedious and awkward for the operator, and cannot be compared with the present method, where the setting of the machine is constant, and loading time eliminated by the use of an index basis.

Further, milling from the root to the tip only eliminates the difficulty of starting the cut on the square end of the combined section, the difficulty of a long blade being drawn off the seat on the fixture when milling at the centre remains, and can only be avoided by downcut milling.

MR. SEED : Is there any particular advantage in using a square tenon against the round tenon ?

MR. HENDERSON : A round tenon is obviously much better than an oval tenon from a production point of view, but on some of the thinner blades it is impossible to obtain a round tenon sufficiently large to secure the shrouding.

MR. BATTY : Are the round ends on the tenon filed to a guage after.milling in two directions. Do you file the ends round to a standard gauge ?

MR. HENDERSON : Yes.

MR. BATTY : Referring again to the question of cleaning. I take it that there is a parallel cut taken over the side faces of the packed sections.

MR. HENDERSON : Yes. The inlet and outlet sides of the segment root are faced up at the same time as the serrations are milled.

MR. RHODES : I should like to ask Mr. Henderson how the segments are built up.

MR. HENDERSON : Assuming 12 packing sections in a segment, these are inserted into a groove in a fixture, and blades inserted between the sections. The blades and sections are then squeezed together at the root by end and side pressure, applied by means of screws provided in the fixture. The shrouding is now rivetted on, or, if the blading is of the radial clearance type, the lacing wires are fitted.

The top half of the fixture is then inverted, and the segment welded along what will ultimately be the underside of the root. The welding holds the segment rigidly together during liquid brazing.

After removing the segment from the fixture, the lacing wires or shrouding, as the case may be, are now brazed, and then the segment root is brazed solid by the dipping method.

MR. GIBSON : May I ask how you get your clearances for the necessary brazing material ?

Mr. Henderson: Ridges are provided on the packing section as rolled, which maintains a small space between the blades and sections when they are assembled together.

Mr. Gray: Do you use any particular kind of high speed steel for cutting stainless blades?

Mr. Henderson: Straight 18% Tungsten H.S.S. gives good results on stainless iron, but on the Austenitic Steels a super H.S.S. containing 5 to 6% Cobalt is to be preferred.

Mr. Swallow (Chairman): Well, Gentlemen, I feel we have had a really good lecture tonight and I call upon Mr. Gibson to propose a vote of thanks to Mr. Henderson.

Mr. Gibson: Mr. Chairman and Gentlemen: I am sure we are all very grateful for this opportunity to hear an expert explaining to us, in the limited time at his disposal, the manufacture of turbine blading.

Quite frankly, when I realised that this was the subject, I considered it to be such a specialised one as to have rather a limited general appeal. I must confess, however, that I am very surprised, and we are all very gratified that we came along tonight to hear Mr. Henderson's very excellent lecture.

So far as turbine blades are concerned, I can recall when I was a very junior planning engineer, trying to find out how to manufacture turbine blades. I have always been rather ashamed of it, but now I am not quite so ashamed as I would have been.

I think there is nothing else but to propose a very hearty vote of thanks to Mr. Henderson for his very excellent lecture.

Mr. Vickery: Well, Gentlemen, I must agree with the proposer that I have thoroughly enjoyed Mr. Henderson's paper, and I do not think I can add anything to the remarks of Mr. Gibson, except to endorse them.

Mr. Henderson: I would like to thank Mr. Gibson and Mr Mr. Vickery for their very kind vote of thanks, and I thank you all, Gentlemen, for listening so patiently to me tonight.

MACHINE SHOP ENGINEERING

Machinists', Turners' and Fitters' Work

Note in regard to the Intermediate Examination in England and Wales.—When an examination in this subfect at a stage corresponding to the Institute's Intermediate Examination is held by an Examining Union recognised by the Board of Education, a Local Education Authority which is a member of the Union will normally arrange that its students at that stage will take the corresponding examination of the Union. The City and Guilds of London Institute will accept for its Intermediate Examination a candidate or candidates from such a Local Education Authority only upon the specific request if the Chief Education Officer of the Authority for Higher Education, confirming that the Authority, having considered the matter, desires the City and Guilds of London Institute to accept the candidate or candidates for the Intermediate Examination.

The scheme of syllabuses and examinations in Machine Shop Engineering (Machinists', Turners' and Fitters' Work) for a grouped course of part-time instruction, both theoretical and practical, is framed with the object of supplementing the student's industrial experience, and so improving his skill and understanding as a craftsman. It is urged that the course of training provided under the scheme should in general be arranged by the technical college in consultation with local employers, so that by a suitable division of instruction and practical work the whole course may be covered in the way that best accords with local circumstances and requirements. The revised scheme has been adopted by the City and Guilds of London Institute upon the recommendation of the Advisory Committee on Machine Shop Engineering (Machinists', Turners' and Fitters' Work) and has the approval of the Institution of Production Engineers.

1. *Course of Instruction.*—The course is arranged in two stages, Intermediate and Final. The minimum age of entry to the Intermediate course should normally be 16 years. The work of the Intermediate stage should occupy at least two years of part-time study, and that of the Final stage at least a further two years. The content of the course in both stages is as follows :—

Workshop Technique.
Science, Calculations and Drawing.
Scheme of Practical Work.

2. *Examinations.*—An Intermediate and a Final Examination will be held by the City and Guilds of London Institute. Each examination will comprise two papers, each of three hours' duration, the first paper to be on Workshop Technique and the second on Science, Calculations and Drawing. There will be no Practical Test, but candidates entering for examination will be required to produce evidence of satisfactory practical training.

3. *Eligibility for the Intermediate Examination.*—In order to be accepted for the Intermediate Examination a candidate must, at the time of entry, be certified by the Principal of the College he has attended to have completed satisfactorily an Intermediate Course in Workshop Technique, and Science, Calculations and Drawing (or in Science, Calculations and Drawing when no course in Workshop Technique is available), and to have carried out satisfactorily at least four of the Sections I to VIII of the Scheme of Practical Work in the Intermediate Course. In cases where a Workshop Practice class has not been taken at the College, the Works Manager may certify, through the Principal of the College, that four sections of the Scheme of Practical Work have been carried out satisfactorily at the works where the candidate is employed.

4. *Eligibility for the Final Examination.*—In order to be accepted for the Final Examination a candidate must, at the time of entry, be certified by the Principal of the College he has attended to have completed satisfactorily a Final Course in Workshop Technique, and Science, Calculations and Drawing (or in Science, Calculations and Drawing when no course in Workshop Technique is available), and to have carried out satisfactorily at least two of the Sections I to IX of the Scheme of Practical Work in the Final Course. In cases where a Workshop Practice class has not been taken at the College, the Works Manager may certify, through the Principal of the College, that two sections of the Scheme of Practical Work have been carried out satisfactorily at the works where the candidate is employed.

5. *External Candidates.*—A candidate in Great Britain or Ireland who for some valid reason is unable to obtain the certification required under Clause 3 or 4 above may apply to the Institution of Production Engineers before February 1st for recommendation to the City and Guilds of London Institute as an external candidate. His application, which should be made upon Form M, obtainable from the Institution of Production Engineers, 36, Portman Square, London, W.1, must set forth a full statement of the circumstances and of his practical training and studies and include a certificate that he has completed the required items of the Scheme of Practical Work for the Intermediate or Final Examination as the case may be.

A candidate who is recommended for acceptance as an external candidate must make his entry through the Local Secretary of an examination centre in the ordinary way ; his entry cannot be accepted directly by the Institution of Production Engineers or by the City and Guilds of London Institute.

6. *Overseas Candidates.*—Candidates entering at overseas centres will be accepted under clauses 3 and 4 provided that they have attended an approved course of instruction including Practical Work. For the present external candidates cannot in general be accepted from overseas centres.

7. *Award of Intermediate Certificate.*—A candidate successful in the Intermediate Examination will be awarded an Intermediate Certificate of the First or the Second Class according to the standard he attains in the examination.

8. *Award of Final Certificate.*—A candidate successful in the Final Examination will be awarded a Final Certificate of the First or the Second Class according to the standard he attains in the examination.

9. *Award of Full Technological Certificate.*—A Full Technological Certificate countersigned by the Board of Education and by the President for the time being of the Institution of Production Engineers will be issued to a candidate who has obtained an Intermediate Certificate in 1944 or subsequently, *or* has passed an equivalent examination held by one of the Regional Examining Unions, *or* has obtained the Ordinary National Certificate in Mechanical Engineering countersigned by the President of the Institution of Production Engineers, *and* has passed the Final Examination. This certificate will be of the First or the Second Class according to the standard attained by the candidate in the Final Examination

Application for a Full Technological Certificate from a candidate who began his course of training under the former syllabuses will be considered on its merits. Such a candidate may be required to produce evidence of having satisfactorily covered the Scheme of Practical Work of the present Intermediate Course.

10. *Exemption.*—A candidate who passes the Final Examination may claim exemption from the paper on Workshop Practice and Processes in the Graduateship Examination of the Institution of Production Engineers.

Syllabuses :—

INTERMEDIATE EXAMINATION.

It is not expected that all parts of the syllabuses will be covered in equal detail or in the sequence shown, and it is assumed that a

suitable proportion of the time devoted to Workshop Technique and to Science will be spent in demonstration work and experiment in workshop and engineering laboratories. But in whatever manner the work is planned, it is essential that class-work and practical work shall be co-ordinated, and that the class-work in Science, Calculations and Drawing shall be closely associated with typical problems in workshop practice.

Workshop Technique (Intermediate).

Materials.

Metals and alloys. The composition, physical properties and engineering uses of the more common metals and their alloys: cast iron, wrought iron, malleable iron, mild steel, medium and high carbon steel, copper, gunmetal, brass, phosphor-bronze, bearing metals and light alloys.

Heat treatment. Simple examples of heat treatment of plain carbon steels. The effect of carbon. Normalizing, annealing, hardening, tempering and case hardening. Simple explanation of critical points and critical range. Description and use of typical heat treatment equipment. Work hardening and treatment when necessary.

Machine Tools and Machining.

The copying or forming, and the generating principles embodied in machine tools.

A general working knowledge of the following machines, their common accessories, and features of construction: lathes, plain milling machines, drilling, shaping, slotting and planing machines. Essential conditions for accuracy in machining, as applied to each machine.

Drilling machine work. Sensitive and pillar type machines. Types of drills and their uses. Marking out for accurate work. Setting up for drilling flat, inclined and cylindrical surfaces. Reaming and counterboring. Tapping attachments. Quick release chucks.

Lathe work. Centre, chuck and face plate methods. Types of chucks, centres, catch plates, carriers, mandrels, steadies, and their application. Turning tools, boring tools and bars. Taper turning. Screw cutting of single-start vee threads. The use of the multi-tool post. Introduction to the use of the hexagon turret.

Milling machine work. Types of milling cutters: cylindrical, side, face and angular cutters, and their application. Gang and straddle milling. Methods of setting up and holding work to ensure accuracy. Machine vises. Devices for direct indexing. Metal slitting operations. End milling: types of end mills and their particular applications.

Shaping machine work. Setting up and machining methods for flat surfaces, vee grooves, keyways, and tee slots.

Jigs and fixtures. Functions of simple types of jigs and fixtures in conjunction with the above machines. Elements of location and clamping as applied to both jigs and fixtures.

Lubrication. Types of lubricants and their particular application, with special reference to bearings, slides, and centres. Use of cutting oils or solutions to improve finish of work or to minimize the rise in temperature of work and tool.

Cutting Tools.

Cutting action of tools: hand tools, lathe tools, drills, reamers, milling cutters, dies and taps. Tool angles for different materials and purposes. The effects of rake and clearance. Selection of suitable cutting speeds and feeds for given conditions. Effects of variation of tool angles, speeds and feeds on power absorbed, endurance of tool, and surface finish. Methods of grinding single-point tools.

Bench Work.

Selection and use of chisels, files, and scrapers in the production of flat, cylindrical and other surfaces by hand methods. The use of surface plate, surface gauge, squares, straight edges, bevel protractors and combination sets in marking out.

Measurement and Gauging.

Measuring equipment: construction, and use of surface plates, straight edges, squares, micrometers (external and internal), vernier callipers, height gauges, dial gauges, rules and protractors. Elements of interchangeability and limit gauging.

Systems of limits and fits for plain and screwed work. B.S.I. standards: B.S. 164, 1924. Tolerances; limits; clearance, interference and transition fits. Types of limit gauges. Advantages of adjustable gauges. Methods used in the production of simple limit gauges of the plug, gap and ring types.

Safety Measures.

A survey of safety measures applying to the workshop generally and to the use of machine tools more particularly, as covered by the current Factories Act.

SCIENCE, CALCULATIONS AND DRAWING (INTERMEDIATE).

Science.

Temperature scales. The melting points of the more important engineering materials: iron, steel and non-ferrous materials, including light alloys. Temperature of soldering and brazing operations. Flame temperatures. Fire, furnace and welding temperatures with different fuels and methods of combustion.

Heat. Specific heat. The measurement of temperature and heat, and their effects on the physical properties of engineering materials: expansion, hardening, tempering, normalizing and annealing.

Force. Measurement. Effect on materials in such applications as stretching, bending, twisting and shearing. Calculations of simple direct stresses.

Leverage. Moment of a force. Examples such as spanners, clamps, operating levers, stocks and dies, taps and wrenches, ratchet and pawl. Calculations based on normal hand efforts.

Turning moment applied to shaft by gear wheel and pulley drives. calculations of pulley sizes and gear wheel trains for given motor and machine speeds.

Work. Measurement. Calculations of work done by the force at the tool point in the operations of turning and shaping, using typical machine feeds and speeds. Power and its workshop applications.

Friction. Assisting clamping; impeding motion. Coefficient of friction. Work lost in bearings and slides. Elementary consideration of lubrication.

Velocity ratio. Application to drives and feed mechanisms. Dial movement in relation to accurate machining dimensions.

Efficiency. Work input and output calculations for the mechanisms incorporated in machine tools.

Calculations.

Arithmetic. Fractions and decimals, with special reference to (*a*) degrees of accuracy required, (*b*) rough checks. Application to micrometer, vernier and other measuring instruments. The metric system and conversion of length dimensions. Averages and percentages, with reference to alloy compositions, machining losses, and output figures. The use of logarithms in multiplication and division, and in the evaluation of formulæ involving single powers and roots.

Mensuration and algebra. Linear measurements; surface, volume, and weights of regular solids. The use of tabulated values for sheets, bars, pipes and rolled sections. Simple graphs of statistics and representations of formulae and expressions. Use of symbolic formulae in the manipulation of algebraic expressions, and the solution of simple equations.

Geometry. The right-angled triangle; relationship between lengths of sides.

Angles and their measurement. Use of tables of sines, cosines and tangents. Simple applications of these ratios to workshop problems, such as setting out and measurement of tapers, profile

gauges and templates. NOTE.—Work to be limited to right-angled triangles.

Drawing.

Interpretation in the light of shop requirements of drawings and instructions received from the Drawing Office. Free-hand dimensioned sketching in good proportion of simple components and machine elements. Sketches and drawings of simple assemblies. NOTE.—*Elaborate or well-finished drawings will not be expected.*

Use of drawing instruments in making workshop drawings, including orthographic projection. Detail drawings of machine parts and simple related component parts properly dimensioned, with all necessary tolerances. Grades of machining. Allowances for various grades of fit

Instructions and references, in accordance with good modern practice, on drawings for issue to shops.

Construction of common geometrical plane figures, including circle and tangents, and their applications to setting out templates, profile gauges and other marking-out problems.

SCHEME OF PRACTICAL WORK (INTERMEDIATE).

The complete scheme of practical work outlined below should be covered if possible during the Intermediate stage, so that a candidate may receive a well-balanced foundation of workshop practice upon which the more specialized work of the Final stage may be built. organizers of technical courses should try to supplement the practical experience gained by the candidate at his work, so as to ensure that his practical training covers as far as possible what is outlined in the scheme.

I. *Marking Out.*

Either (*a*) a steel or cast iron component for machining, in which the following operations are planned : facing by turning, milling or other general machining method, drilling, boring and counterboring.

Or (*b*) a plate gauge demanding the use of height gauge, bevel protractor or combination set and other marking out equipment.

II. *Fitting and Bench Work.*

Either (*a*) the fitting of two mating parts requiring the use of chisels, files, scrapers, drills, reamers, hand taps, stocks and dies, in which the important dimensions are to tolerances recognised in good class practice.

Or (*b*) the soldering and brazing or, alternatively, the welding of simple lap or butt joint with steel or copper plate.

III. *Tool Grinding.*

The hand grinding of a representative selection of single-point tools to standard shapes and angles for specified machining operations.

IV. *Turning.*

Centre lathe turning and boring, including chucking operations with both three- and four-jaw chucks. Taper turning. The cutting of a single-start Whitworth or square thread.

V. *Milling.*

The milling of flat surfaces, and of vee grooves, slots or keyways in which the widths and spacings are to tolerances recognized in good class practice.

VI. *Shaping, Planing or Slotting.*

The machining of flat faces, with vee grooves, tee slots, or other work requiring similar operations.

VII. *Grinding.*

Either (*a*) external (parallel and taper) or internal (cylindrical) grinding.

Or (*b*) surface grinding of parallel faces, to tolerances and finish recognized in good class practice.

VIII. *Heat Treatment.*

The preparation and heat treatment of a typical selection of plain carbon or alloy steel cutting tools for hand or machine work.

FINAL EXAMINATION.

As in the Intermediate stage, it is not expected that all parts of the syllabus will be covered in equal detail or in the sequence shown. Demonstration work and experiment in workshop and engineering laboratories should be continued as part of the courses in Workshop Technique and in Science, the co-ordination of class work and practical work should be maintained, and the work in Science, Calculations and Drawing should still be closely associated with typical problems arising in workshop practice.

Workshop Technique (Final).

The syllabus is divided into a General Section and five Special Sections A, B, C, D, and E. Candidates will be expected to cover the General Section and one or two (but not more than two) of the Special Sections A, B, C, D and E. The question paper will contain a sufficient number of questions on each Special Section to enable the candidate to confine his answers to one of these sections but he may, if he wishes, answer questions from two Special Sections.

In both the General Section and Special Sections, more difficult questions may be set on the subject matter of the Intermediate Syllabus as well as questions on the following :—

General Section.

Materials.

Metals and alloys. Composition and properties of high-duty cast irons, cast steels, the principal alloy steels, non-ferrous alloys, and aluminium and magnesium alloys, commonly required as tools or materials for production.

Heat treatment. Methods of measuring furnace temperatures, heat treatment of special alloy steels, high-speed tool steels and alloy cutting tools. Apparatus of a typical heat treatment shop. Scleroscope and ball or diamond pyramid hardness tests.

Machine Tools and Machining.

Lathe work and milling machine work. Extension of the work of the Intermediate Syllabus to deal with the use of these machines for general work. Types and uses of collets. Use of thread chasers, die heads and taps in lathe operations. Introduction to the use of turret and capstan lathes with standard tools. Introduction to the operation of the universal milling machine.

Grinding machine work. Operation of plain and universal cylindrical grinding machines with internal grinding equipment. Selection of wheel for typical operations and materials. Wheel dressing. Relation of wheel, work and table speeds for these operations with wet and dry grinding. Honing and lapping

Planing, slotting and shaping machine work. Operation of the more common types of machines and tools in general use. Methods of setting-up, holding and clamping for general work.

Workshop methods of checking the more important alignments and accuracies of these machines. Special features of construction for the maintenance of accuracy, such as the use of adjustable bearings.

Simple operation lay-outs. Sequence of machining operations in piece, batch and quantity production. Reduction in scrap by intermediate process and material inspection.

Safety measures in relation to these machines.

Cutting Tools.

Typical cutting tools including solid tools, tool bits, welded shank tools, tipped tools, diamond tips. Use of high-carbon steel, high-speed steel, stellite and tungsten carbide. Special tools including three- and four-flute drills, D bits, reamers, broaches, taps, dies and chasers.

Form tools, plain and formed milling cutters. Materials used and toolroom operations in their production and maintenance.

Selection of steel or cutting alloy for material and operation involved. Speeds and feeds in relation to cutting tools used. Methods of ensuring accuracy and good surface finish.

Jigs and Fixtures.

General features. Simplicity, ease and quickness of operation, rigidity, durability swarf and coolant disposal. Typical examples of plate, channel, box and latch type drilling jigs. Simple lathe face plate and milling machine fixtures.

Location and clamping. Selection of locating points and surfaces for (*a*) first and (*b*) sebsequent operations. Types of locating pins, fixed and sliding vee locations, jacks and supporting pins. Clamping devices and their particular applications. Drill bushes, types and applications, standardisation.

Measurement and Gauging.

Production of " workshop " and " inspection " limit gauges to British Standard Specifications for a typical component requiring plug, gap and ring gauges. Testing such gauges by comparison with standards, consideration of allowance for wear.

B.S.I. standards of accuracy for straight edges, micrometers, surface plates and flats, precision levels, slip gauges, comparators, etc.

Methods (including projection) of gauging tapers, vees, dovetails and special forms.

Measurement of screw threads by micrometer and three-wire system. Limit gauging of screw threads in accordance with British Standard Specifications.

Section A—Turning, including Vertical and Horizontal Boring.

The general features of construction of standard workshop and toolroom lathes, boring and turning mills, and boring machines. Machining capabilities and typical operations, including application of multi-tool operations. Alignment tests for these machines and their standard accessories.

Boring, facing and turning operations upon large components involving detailed setting up on the face plate or boring table, balancing of work, mounting and clamping of tools for heavy cuts to avoid chatter. Use of these machines in machining engine cylinders and frames, jigs and fixtures, to tolerances and finish recognized in good modern practice, with use of slip and dial gauges for setting up.

Section B—Tool Setting.

Turret and capstan lathes with special reference to tool setting for semi-skilled operators. Types: range of speeds and feeds for typical machines. Chuck and bar lathes, methods of holding and feeding work. Square and hexagon turrets.

Tools and attachments including roller steady and centring tools, box tools, combination tools, floating tools and reamers. General features of design and operation including indexing trips and stops.

Tool mounting and setting to ensure accuracy of reproduction, full use of given tolerances, and freedom from chatter. Use of die heads and collapsible taps. Use of the cross slide for facing, recessing, knurling and parting off.

Tool lay-outs and setting up operations considered in relation to typical components.

Section C—General Machining.

Milling. Extension of the General Section to include the use of horizontal, vertical and universal machines for typical general machining work. Essential features of the universal milling machine. Use of dividing head for plain and spiral milling. Use of the milling machine for die sinking and jig boring.

Grinding. Essential features of the universal grinding machine. Methods of grinding threads, gears, splines and helices. Centreless grinding.

Broaching. Principle and use of the machine and tools to produce shaped holes. Lubrication, maintenance.

Gear Cutting. Common methods of gear cutting. Types of cutters for spur and helical gears, including rack, circular cutter and hobbing processes. Production of square, hexagonal and splined shafts.

Measurement and gauging of gear teeth and splined shafts, by use of workshop gauges and measuring equipment.

Section D—Fitting and Millwrighting

Fitting and Bench Work. The use of surface plate, angle plate, squares, protractors, dial indicators and vernier height gauges in the setting up and marking off of machine components for drilling and machining. The preparation of flat and cylindrical mating surfaces.

Millwrighting. Installation of machine tools for unit and group drives. Flat belt, vee belt and vee on flat drives for machine tools. Belt speeds and power transmitted ; joints in belts, endless belts. Erection of countershaft with striking gear, alignment of shafts and pulleys. Types of clutch used in machine tool transmission : adjustment and maintenance. Alignment of transmission gear, bedding down of machines.

Machine tool maintenance and repair. Adjustments for wear with plain, ball or roller bearings for spindles. Scraping in of bearings and of machine slides.

Adjustment of machine slides, fitting of keys of various types. Alignment of machine tools after overhaul using precision methods with dial gauge indicator.

Repair of machine parts—brackets, handwheels, levers, gear wheels—by various methods, including brazing and welding.

Section F.—Toolmaking.

Bench work. The use of universal bevels, protractors, precision squares, straight edges, levels, height gauges, buttons, sine bar and slip gauges for marking out and setting up.

Toolmakers' clamps, vices and files as used in the production of gauges, jigs and fixtures, and press tools.

Machine work. The production of drills, reamers, taps and dies, form tools, milling cutters, gauges, using lathe, milling machine, cylindrical and surface grinding machines, tool and cutter grinder, relieving lathe or attachment, bandsaw and filing machine and other toolroom machines. Use of the circular dividing table and the equipment mentioned above under Bench Work.

Cutting Tools. Control of heat treatment. Grinding of form tools after treatment. Construction and setting of expanding and inserted blade tools. Grinding and re-setting of tipped tools.

Measurement and Gauging. Measurement of limit gauges, profile gauges, using standard toolroom equipment including comparators and projectors.

Toolroom inspection methods for all the work included in this section.

SCIENCE, CALCULATIONS AND DRAWING (FINAL).

More difficult questions may be set upon the subject-matter of the Intermediate Syllabus, in addition to questions on the following :—

Science.

Heat. Heat-resisting materials. Refractories. Methods of temperature measurement using seger cones, thermocouples and optical devices.

Relationship between heat and mechanical energy. Generation of heat in cutting operations. Power absorbed.

Mechanics. Application of vectors. Forces in sling chain, toggle wedge, and at tool cutting point.

The balancing of work on lathe face plates.

Friction. Further examples on friction between various materials. Workshop examples such as lathe saddle movement by rack and pinion ; holding down force required between fixture and machine table to withstand various machining operations ; axial pressure between milling cutters and collars to withstand cutting forces.

Mechanical efficiency of the more common workshop machines. Consideration of losses.

The inclined plane. Bolt and nut tightening and loosening, vee threads and square threads. Vee belt drives.

Young's modulus. Stress and strain, and elastic limit.

Simple consideration of the effects of speed and size on the power transmitted by a shaft and friction clutch.

Calculations.

Manipulation of formulæ and construction and solution of equations.

Trigonometry, and the solution of right-angled triangles. Calculations of co-ordinate hole centres.

General workshop calculations applicable to the following :— B.S.I. limit systems, spirit level and its graduations, the sine bar, the gauging of large radii and measurement of large bores, the measurement of tapers and dovetails by means of balls and rollers, wire measurement of screw threads, the dividing head, arithmetical and geometrical progression of speeds and feeds, tool angles, true shape of form tools, cutting power for turning and drilling.

Drawing.

Hand sketches of jigs, fixtures, tools and gauges, required for the production of various classes of machined components. Simple orthographic drawings requiring the assembly of detail, the abstraction of detail, or the addition of omitted details. Correct methods of dimensioning ; machining limits and other instructions on drawings. B.S.I. specifications, material specifications and operation lay-outs in relation to the various items dealt with.

Geometry. Sections of right circular cone by vertical and inclined planes ; intersection of solids having axes in the same straight line or intersecting at right angles.

Scheme of Practical Work (Final).

The candidate should cover *at least* two and as many more as time permits of Sections I to IX of the scheme set forth below. The sections chosen should be related to the Special Section or Sections to be selected by the candidate in the paper on Workshop Technique.

I. The marking off, setting up, andm achining in a lathe, of a casting, forging or fabricated part requiring at least two settings for accurate relationship of bores or surfaces. At least one of the operations should require the use of face and angle plate.

II. Layout of operations, and setting up of a typical multi-tool capstan or turret lathe, for the production of a part requiring, as far as possible, full use of the tooling available. Either collet or chucking capstan would be suitable.

III. Machining to appropriate limits a number of parts forming an assembled unit, such as a " tool-maker's jack " embodying as many as possible of the following operations: surfacing, facing, recessing, boring and screw cutting (internal and external). The parts should be, as far as possible, of different materials.

IV. The machining of a component on a universal milling machine in which a variety of operations and cutters is used. The work should include indexing and, if possible, some spiral milling.

V. The grinding of a component on a cylindrical grinding machine, fitted with internal grinding attachment, in which internal and external grinding of parallel and taper work to toolroom limits is required, *or*, alternatively, work of equivalent standard on a surface grinder or tool and cutter grinder.

VI. The machining of a component (steel or cast iron), such as a simple milling fixture, requiring the following operations: planing or shaping, drilling, reaming and counterboring.

VII. The assembly of a mechanism requiring accurate alignment, the fitting of bearings, and various drilling, reaming, tapping and dowelling operations.

VIII. The production of a set of workshop gauges comprising plug, gap and recess, limit gauges, for checking a component to British Standard Specifications and Recommendations. Suitable gauge blanks should be provided, but all heat treatment and finishing processes should be carried out.

IX. Manufacture of a simple press tool, such as a "drop-through" type blanking tool with fixed stripping plate.

THE GANTT CHART AS AN AID TO PROGRESS CONTROL

Paper presented to the Institution, London Graduate Section, by A. W. Swan, B.A.Sc. (Toronto).

THE Gantt Chart is a practical tool of great importance to management. Its greatest advantage is its simplicity and remarkable adaptability. Readers are urged to apply these charts to their own problems.

Summary.

1. The advantages of the Gantt Chart are stated :—
   - (*a*) Emphasis on comparison of Performance against Programme.
   - (*b*) Correctness of visual impressions.
   - (*c*) Simplicity.
   - (*d*) Compactness.
   - (*e*) Adaptability.
   - (*f*) Economy in staff.

A practical manufacturing example is given, showing the advantage of the Gantt Chart in comparison with other types of record and chart.

2. A simple adjustment for Gantt Charts when a change of Programme occurs is illustrated.

3. The use of the Gantt Chart to provide running stock figures of material available for work in terms of the latest programme of the finished job is worked out.

4. The use of the Gantt Chart to follow manufacture through from material (*e.g.*, forgings) to the finished product (*e.g.*, cut gears) ; with visual check on time-lags due to inspection, transport, etc., is demonstrated.

Types of Chart.

Charts can be divided for convenience into two main classes :—

(1) For Industrial Use.

May 9, 1942.

(2) For Calculation, *e.g.*, alignment charts, used as an alternative to special slide-rules.

Class (1) includes a great variety of types, but these can be sorted out into three main divisions :—

(*a*) The new Quality Control chart on squared paper, developed in the U.S.A. by Shewhart & Simon, and in Great Britain by Dr. Dudding. This has a very real value to the production engineer, but is not applied to direct progress control.

(*b*) Graphs on squared paper.

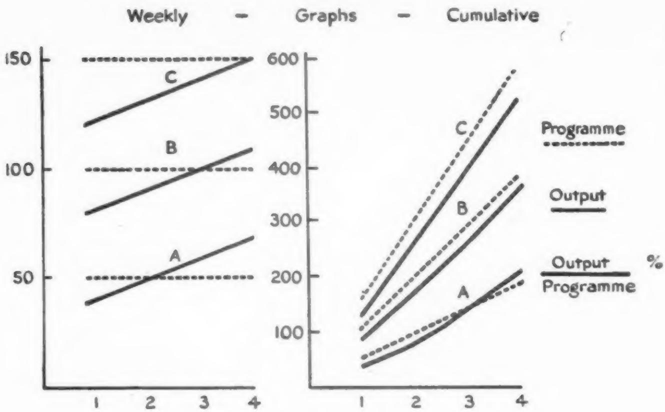
(*c*) Continuous bar charts.

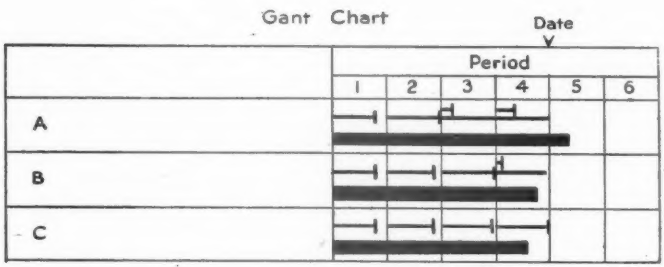
The Gantt Chart is a special form of continuous bar chart. Its special distinction is that it reduces all performance to the basis of a measurement against a quota per period of time on the percentage basis, with two sets of lines, one showing the percentage of performance against programme within the period, the other showing the cumulative performance in percentage up to the end of the latest period recorded.

The advantages are best shown by actual comparison, Let us take, for example, three factories varying in plant capacity, and making the same product. The programme and outputs are :—

A ...	Programme	50 per period		Output	40	50	60	70
B ...	,,	100	,,	,,	80	90	100	110
C ...	,,	150	,,	,,	120	130	140	150

			Period			Date		
			1	2	3	4	5	6
	Programme	Per	50	50	50	50		
		Cum	50	100	150	200		
A	Output	Per	40	50	60	70		
		Cum	40	90	150	220		
	Output % Programme	Per	80	100	120	140		
		Cum	80	180	300	440		
	Programme	Per	100	100	100	100		
		Cum	100	200	300	400		
B	Output	Per	80	90	100	110		
		Cum	80	170	270	380		
	Output Programme	Per	80	90	100	110		
		Cum	80	170	270	380		
	Programme	Per	150	150	150	150		
		Cum	150	300	450	600		
C	Output	Per	120	130	140	150		
		Cum	120	250	390	540		
	Output Programme	Per	80	87	93	100		
		Cum	80	167	260	360		





The figure shows the information set out as :—

(1) A complete working table showing actual figures and percentages.

(2) A graph on squared paper showing period programme and percentage.

(3) A graph on squared paper showing cumulative programme and performance.

(4) A Gantt Chart.

It will be noticed that the period graph on squared paper is definitely misleading. The slopes of all three output lines are the same, and the first visual impression is that performances are therefore similar. Close inspection shows that A crosses and improves on its programme sooner than B, and B sooner than C, but there is no visual indication that A is improving on its progıamme at a faster rate than B, and B at a faster rate than C; that the

cumulative performances in relation to programme are in the same order, *e.g.*, A, B, C ; or that the final outcome is that the cumulative effort of A is .4 period ahead on programme, that B is 0.2 period behind, and that C is still further in arrears (0.4 period).

The cumulative graph is very little better. It shows by the gaps between programme and output lines that C is worse than B, and that B is worse than A, and the impression given by the slopes is definitely false, C which has the worst performance having the steepest slope.

The Gantt Chart shows the true position at a glance. The A cumulative line is .4 period ahead, B .2 period behind, C .4 period behind, while the period (thin) lines show the relative period positions.

The fact that comparative charts drawn on ordinary squared paper are misleading is well known, and there are accurate alternative methods, notably the use of logarithmic paper or the plotting of percentages. Logarithmic paper is expensive and not suitable for explanation to a busy shop manager, while the plotting of percentages on ordinary squared paper is not nearly so compact as the Gantt Chart, nor so flexible, and it cannot be applied at all to the special uses explained later in this paper.

The advantages of the Gantt Chart for progress work can be summarised as follows :—

(1) Emphasis is always on performance in relation to programme.

(2) Visual impressions are correct.

(3) The chart is simple to read. Anyone can grasp the principles behind the drawing of the period thin (percentage) line and the cumulative thick line.

(4) Accurate comparisons can be made, easily and quickly, of performance against programme, of shops or factories differing in output even to a big extent ; there are no scale difficulties.

(5) The Gantt Chart is flexible, it can be used for relating sub-assemblies to main assemblies, for relating supplying of raw material to output, for financial aspects of shop management, *e.g.*, output against cost budget, etc.

(6) The Gantt Chart is compact, requires less paper than any kind of graph or any continuous bar chart.

(7) It is economical to operate. No mathematical knowledge or special draughtsmanship is required by the operators.

Effect of Change of Programme on the Gantt Chart.

A practical point which has had little consideration is the fact that unless adjustment is made when changes of programme are made, the cumulative Gantt line, if built up from period percentages,

will not convey the true picture as to how much performance is behind or ahead of programme.

Consider the case of a programme which rises from 50 to 200 units per period in steps of 50 units, and then remains at 200 units per period, while the output remains steady at 90 units, and that we are just starting period 4. The information is shown in tabular form below.

		Period 1	2	3	Date 4	5	6
Programme	Period	50	100	150	200	200	200
	Cumulative	50	150	300	500	700	900
Output	Period	90	90	90			
	Cumulative	90	180	270			
$\frac{\text{Output}}{\text{Programme}}$ %	Period	180	90	60			

The cumulative deficit to date is : Cumulative Programme 300 Cumulative Output 270. Cumulative Deficit 30.

In terms of the current programme which we are about to start in period 4 and which is therefore of practical interest now, we are $\frac{30}{200} = .15$ period behind on programme. We shall have to make this up in addition to our period quota, if we are to be level with our cumulative programme at the end of period 4.

In terms of the programme of 150 per period we have just finished we are $\frac{30}{150} = .2$ week behind on programme.

If we draw a normal unadjusted cumulative Gantt line consisting of the sum of the period percentages, to the end of period 3, we have $180 + 90 + 60 = 330$, which graphically shows that we are .3 week ahead. This result is as we have just shown false on the basis of either the 150 (old) or 200 (current) programme, and some adjustment is clearly necessary.

The adjustment is quite simple and is made as follows :

1. Neglect all previous changes of programme. Example: Neglect the change from 50 to 100, and from 100 to 150.

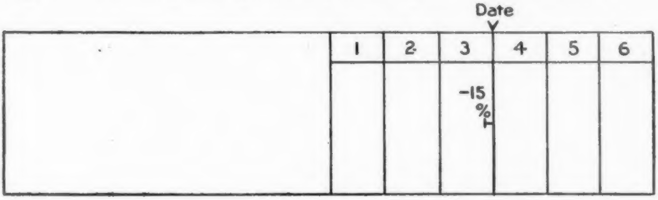
2. At the point of change to the current programme find the cumulative excess or deficit of output on programme in units. Example : At the end of Period 3 (or beginning of Period 4) when

the programme changes to the current one of 200, the cumulative deficit is 300 — 270 = 30 units.

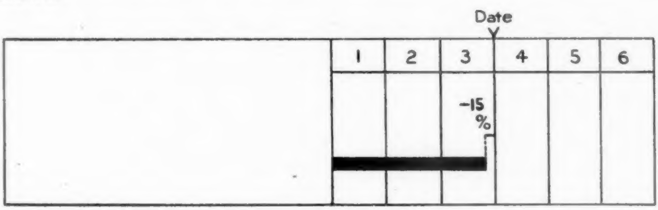
3. Calculate this cumulative excess or deficit as a percentage of the current programme (not the programme just completed).

Example: Deficit as percentage of current programme equals $\frac{30 \times 100}{200} = 15\%$.

4. Draw a line forward (right) for an excess or backward (left) for a deficit from the beginning of the first period of the current programme corresponding to the percentage calculated above.



5. Draw the cumulative line level with the end of the line just drawn.



The adjustment is now complete and the cumulative line as now drawn shows the position at the start of the current programme in terms of that programme (in the sample .15 week behind). A moment's reflection will show that this is the information which management will require from the chart, not what the position is in terms of programmes that have gone or may come in the future, but what it is in terms of the current programme.

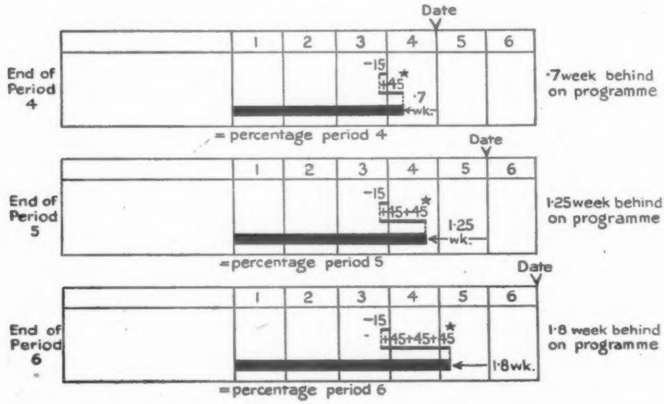
Once the adjustment is made, the cumulative line is built up in the ordinary Gantt way by adding on the period percentages, period by period, until another change of programme occurs, when a similar adjustment is made.

Consider for instance, that in the example taken above the

programme remains at 200 per period and the output remains at 90 per period. In tabular form the position when we have reached the end of period 6 will be as follows :

		1	2	3	4	5	6
Programme	Period Cumulative	50 50	100 150	150 300	200 500	200 700	200 900
Output	Period Cumulative	90 90	90 180	90 270	90 360	90 450	90 540
Output/Programme %	Period	180	90	60	45	45	45

and the graphical stages will be :



At the end of Period 6 the cumulative line shows 1:8 week behind on programme. The actual cumulative deficit as shown by the table is 900 — 540 = 360. At a programme rate of 200 per week, the cumulative deficit is $\frac{360}{200} = 1.8$ week so the position is 1.8 week behind programme, as correctly shown by the chart.

Gantt Chart for Running Stock Figures.

On one application the Gantt Chart has no competition. By setting cumulative lines of input and output side by side a running stock figure is provided, period by period, in terms of the programme. Thus, a manager, by inspecting his Gantt Chart can see, not only

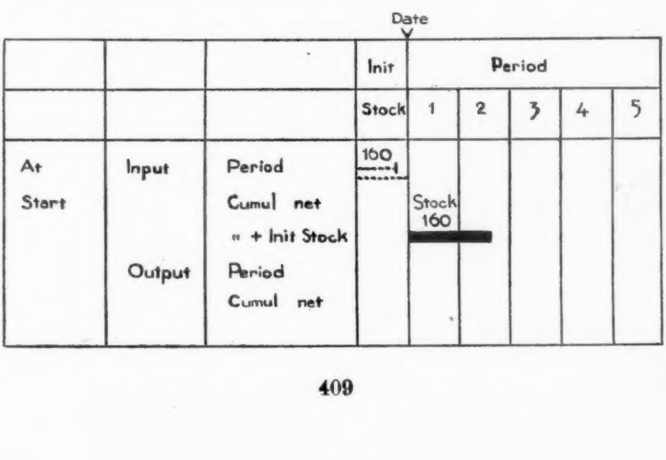
how production for many items is keeping pace with the Programme, since the cumulative line for each one should at least march level with the date, but the available stock of incoming material (castings, forgings, etc.). Furthermore, however the programme may change, if adjustments are made as described in the proceeding section, the running stock figure is always in terms of the latest programme. This latter point is important, as when for instance a programme is increased from 40 to 80 units per period the manager wants to know how his stock of material is in terms of the 80 per period, not the 40 per period programme.

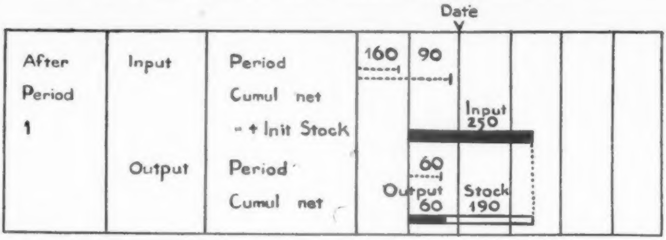
At the beginning of Period 1, the cumulative input line will be the initial stock existing at that time, and the position will be shown as on the diagram opposite. It is to be noted that though the initial stock is shown in a separate column, it belongs in effect to Period 1, and the cumulative line is drawn in the ordinary way from the beginning of Period 1. At this stage there is of course no output line .

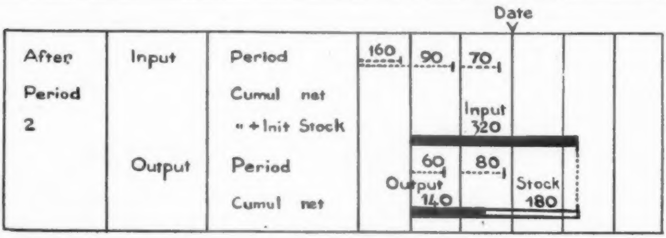
At the end of Period 1, the input cumulative line shows the initial stock plus the receipts of the period and the output cumulative line shows the output of the period. The available stock of material is initial stock plus receipts, minus output, and it is shown by the difference between the input and output lines.

At the end of Period 2, the input cumulative line shows the initial stock plus receipts for periods 1 and 2 ; the output line shows the output for periods 1 and 2, and the difference shows the current stock of material available.

A typical example is shown opposite in the three stages. When there is a change of programme the procedure is exactly as when starting from zero, the cumulative excess or deficiency being treated as a plus or minus initial stock.







Application of the Gantt Chart to Time-lag due to Inspection, Transit, etc.

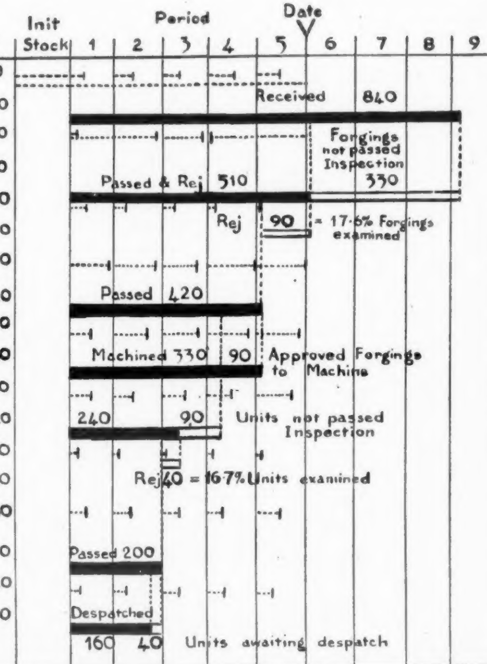
In many factories, engineering and otherwise, the problems have to do with a series of operations on the same material. If input and output from process to process is regular, which means that the time-lag in the stages from entry to the factory to exit as finished product is fairly constant, there is no need to go further than to find out what the lags are, and calculate accordingly, making suitable allowances for loss of material and deficitives. In such cases, a straightforward system of Gantt production charts does very well; a particular (actual) example being for instance a factory making magnesium powder in six stages. A plain Gantt chart is used for each stage with complete success.

A large number of processes are however subject to variable delay at one or more stages due to inspection, transit, etc., a particular case in munitions being the filling of fuses, since proofing depends to some extent on the weather, and the number under proof is an important factor in output. On the other hand it may be difficult to balance exactly input against output, such as in soap-making where material is added to and drawn from vats, but it is never a case of following a definite batch right through from raw material to finished product.

By a simple extension of the principle of the running stock figure, the Gantt Chart can be applied successfully to the solution of these awkward problems.

The following table and chart show the application of this method

			Init Stock	Period 1	2	3	4	5
Forgings	Received	Per	210	120	130	130	140	110
		Cum	210	330	460	590	730	840
	Passed for Machining & Rej	Per	–	110	90	90	110	110
		Cum	–	110	200	290	400	510
	Rejects	Per	–	30	20	20	10	10
		Cum	–	30	50	70	80	90
	Passed	Per	–	80	70	70	100	100
		Cum	–	80	150	220	320	420
Units	Machined	Per	–	40	65	70	75	80
		Cum	–	40	105	175	250	330
	Passed for Despatch & Rejects	Per	–	35	45	50	50	60
		Cum	–	35	80	130	180	240
	Rejects	Per	–	5	5	10	10	10
		Cum	–	5	10	20	30	40
	Passed	Per	–	30	40	40	40	50
		Cum	–	30	70	110	150	200
	Despatched	Per	–	10	30	40	40	40
		Cum	–	10	40	80	120	160



to a factory receiving forgings, inspecting them, machining, inspecting and despatching the machined units.

As in charts shown earlier, the output programme is taken as 100 units per period, so that actual figures also represent percentages.

The basic principles in what may be called the inverted staircase use of the Gantt Chart for the following through of material from arrival to despatch are :—

1. All figures are in terms of the final programme of finished units, this being the only programme which really interests the management.

2. Except for entry of raw materials and despatch of the finished product each cumulative line is used in two capacities, (*a*) as the bottom of one step, and (*b*) as the top of the next step. For example, in the figure opposite it will be noted that the first cumulative line, for forgings received, is only used once, as the top of the first step ; the next cumulative line, forgings passed and rejected, is the bottom of the first step showing by difference the number of forgings still not passed inspection, and it is also the top of the next step showing by difference the number of forgings passed.

It will be noted that the cumulative line for rejects is drawn in the way shown instead of from the base, and in practice it is drawn in pencil and altered from period to period. It will further be noted that apart from the main uses of the chart to show time-lag at all stages in manufacture, the cumulative rejects line is a highly useful check on quality of material and machined units. The proportion of rejects is clearly shown, and it is a simple matter to write in the percentage. This percentage for the cumulative line is of course based on the total number of forgings or machined units examined to date, (if necessary an ordinary Gantt cumulative rejects line starting from the beginning of Period 1 can be used to show rejects against programme).

Examination of the weekly and cumulative lines in the foregoing chart reveals a melancholy tale, as follows :—

Receipts of forgings are quite good, supply for two periods having been on hand to start machining at the beginning of Period 1, and regular supplies of 110 to 130 per period having come in since work began.

Inspection of forgings has not kept pace with receipts, however, The stock of forgings not passed inspection has increased to nearly 3½ periods on programme at the end of Period 5 and barely enough have been passed for machining to maintain full output to programme. The period inspection line shows an improvement in the last two periods, however, and this may be the forerunner of greater efficiency.

The quality of the forgings has been poor, with an average of nearly 18% rejected from the number examined. If this percentage is maintained, deliveries will have to be increased if the programme is to be met.

On the machining side, efficiency has also been low, 40% to 80% of programme. There has, however been a steady improvement, to such an extent that the number of forgings available for the machines is becoming steadily less, and it will not be possible to increase the rate of machine output much further until the supply of good forgings improves.

Inspection of machined units is also on the slow side, and it is not keeping pace with the increasing production, so that there is a time-lag of nearly a week (on programme) of finished units not passed inspection. Quality of machined units is also very poor, rejections averaging the high figure of 17% on total examined.

Despatch is reasonably efficient, and keeping pace with receipts of finished units from final inspection, the time-lag about half a week on programme, being due to the initial delay.

Summing up, it is seen that at the end of Period 5 out of 840 forgings received, only 160 have been despatched; 330 remain as forgings not yet passed inspection, 90 as approved forgings waiting to be machined, 90 awaiting despatch. The remainder is made up of 90 rejected forgings and 50 rejected machined units.

The above deductions are correct; they can be made quickly; they can be made easily by any executive from manager to foreman, they can be made from a single sheet of paper which shows not only the chart but the supporting figures.

Notes on the Discussion

The discussion, which was lively, pointed, and interesting, took mainly the form of questions and answers. It ranged over a variety of applications for the Gantt Chart and can be summarized as follows:

QUESTION: Is the Gantt Chart cheap to run?

ANSWER: Yes. Records must take some form, detailed for lower management, summarized for higher management. All forms of record cost money to operate. The Gantt Chart scores in economy because of its simplicity. No mathematics are required beyond percentages, and the drawing of the charts is easy. It scores heavily in economy because of its compactness, particularly in comparison with graph charts.

QUESTION: Can the Gantt Chart be applied to jobbing work?

ANSWER: It is difficult to define the lower limit of production flow to which the Gantt Chart can be applied. It would scarcely

be used in a jobbing shop with very small lots, but it is used quite successfully for medium sized quantities.

QUESTION: Can the Gantt Chart be used for work where setting up time is an appreciable part of the total time used?

ANSWER: Yes, if setting up is time-studied and set against a scheduled time. It becomes a part of the time to be set against programme and can readily be indicated as distinct from machining time.

QUESTION: Can the Gantt Chart be applied to determining programmes and laying out work?

ANSWER: Yes, see the books on the Gantt Chart dealing with this aspect.

QUESTION: Is the Gantt Chart inferior to the cumulative graph on the score that equations may be calculated from the curves of performance with a view to predicting future performance.

ANSWER: Yes. From this point of view it may be worth while to have a summary graph on squared paper (periodical or cumulative on arithmatic or semi-log paper) for the purpose of attempting to predict future performance.

QUESTION: What are the principal books on the Gantt Chart?

ANSWER: There is a very good section in Alford's "Cost and Production Handbook," a general book by Wallace Clark, and a good chapter in K. G. Karsten's "Charts and Graphs."

Research Department: Production Engineering Abstracts

(Edited by the Director of Research)

NOTE.—*The addresses of the publications referred to in these Abstracts may be obtained on application to the Research Department, Loughborough College, Loughborough.*

ELECTRICAL ENGINEERING.

Overheating of Electric Motors. (*Mechanical World, September 18, 1942, Vol. CXII, No. 2907, p. 263, 3 figs.*).

Causes and remedies from the maintenance engineer's point of view. Restricted ventilation. Thermal overload capacity of electric motors. Motor loading. Starting. Starting current of typical squirrel cage A.C. when switched directly on the mains. Connections and power supply. Electrical faults. Mechanical faults.

EMPLOYEES (WORKMEN, FOREMEN, APPRENTICES, STAFF).

Foremanship Development in Great Britain, Parts I, II, III and IV, by F. J. Burns Morton. (*Engineering, August 28, September 4, 11, 18, Vol. 154, Nos. 3998, 3999, 4000, 4001, pages 163, 183, 203, 223, 26 figs.*).

The need for development. Foremanship, it should be explained also, is meant to comprise all those persons of either sex who exercise executive authority in industry and who rank between the management and the workmen (or women), whether they are regarded as superintendents or supervisors, overseers, or charge-hands. General and fundamental aims in developing the foreman's efficiency. The results to be expected from the adoption of suitable means for foremanship development can be summarised as: (*a*) better understanding between management and foremen; (*b*) improvement in the executive capacity of the foremen; and (*c*) higher production and more teamwork from the operatives.

Improving older and established foremen. Typical agenda: (1) Departmental output efficiencies. (2) Progress of orders; (3) General routine; (4) Cleanliness; (5) Suggestions.

Training younger and prospective foremen.

FOUNDRY, MOULDING.

A Mechanised Light-Alloy Foundry. (*Aircraft Production, October, 1942, Vol. IV, No. 48, p. 592, 28 figs.*).

In this concluding article of the Rolls-Royce Merlin production series, the highly efficient pattern shop is described and some of the ingenious methods which have been adopted to overcome the difficulties arising from the employment of unskilled labour. The rigid control of sand, materials and castings by the foundry laboratory ensures consistent results.

Designing for Foundry Production, by E. Geiger. (*Amer. Foundrymen's Assoc., Preprint 42-43, April, 1942, p. 16*).

A plea for the better understanding of foundry problems by engineers and designers.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

CHIPLESS FORMING.

Forging Aluminium Alloys, by Herbert Chase. (*The Machinist, September 5, 1942, Vol. 86, No. 21, p. 491, 5 figs.*).

Round forging stock is sheared into short lengths ready for use in producing drop forgings. A cast aluminium billet is handled by a manipulator as it is broken down to a forging billet in a 3,000-ton press. Thickness tolerances on forgings up to ½ lb. in weight are minus 0.010, plus 0.032 in. As weight increases, the thickness tolerance increases until for forgings 24 lb. and over it becomes minus 0.032, plus 0.093 in. Allowance for machining is usually 1/16 in. for small and medium forgings and ⅛ in. on large forgings. Control of dimensions. A propeller blade is removed from the forging die. The die surfaces are polished and oiled for better finish and longer life.

MANUFACTURING METHODS.

Line Assembly of Liberators. (*Aircraft Production, October, 1942, Vol. IV, No. 48, p. 586, 13 figs.*).

Line assembly in the true sense of the phrase has hitherto found very few applications in aircraft production. In the cases where it has been employed, machines of the smaller types have usually been concerned. Although as a load carrier and a fighting machine generally, it is not conceived on the same scale as our own four-engined aircraft, the American Liberator comes into the largest class of heavy bomber and the present article is of special interest as showing how the line assembly system can be applied to aircraft of the biggest type.

Motor Cars to Munitions in U.S.A., Parts I and II. (*The Machinist, September 19, 26, 1942, Vol. 86, Nos. 23 and 24, pages 549, 573, 42 figs.*).

Chrysler, Ford. "Didn't wait for new machines; revamped the ones they had." General Motors. Buick. Cadillac. Chevrolet. Fisher. Oldsmobile. Pontiac. Hudson. All-divisions output of war goods now billion a year, and climbing.

Metal Surgery, by H. H. Hollis. (*Welding, September, 1942, Vol. X, No. 8, p. 184, 24 figs.*).

Metal surgery is the art of treating injuries or diseases of steelwork by manual operations. In order to carry out the operations speedily and effectively arc welding plant is the most important part of the equipment. Examples: (1) three lift spiral guided holder in steel tank, 90 ft. diameter. (2) Two lift gasholder. (3) Two lift column guided gasholder in an underground tank, 104 ft. diameter. (4) Cup and dip repair on a three lift spiral guided gasholder. The inner lift cup leaked and lost the seal. (5) Weakness found on many gasholders with twin top curbs.

Adjustment of Bevel Gears in Assembly I II. (*The Machinist, Machinist Reference Book Sheet, September 5, 1942, Vol. 86, No. 21, p. 529, 5 figs.*).

Mounting bevel gears. Mounting distance. Backlash. Installing the gears. Marked teeth. Mountings. Locating the pinion. Locating the

gear. Ideal bearings for spiral bevel gears. Checking the installation. Tooth bearing of spiral bevel gears.

Design and Production Technique, by A. J. Schroeder. (*Aircraft Engineering, September, 1942, Vol. XIV, No. 163, p. 265, 42 figs.*).

Principles involved in die-casting. Die-casting technique comprises those casting methods in which liquid metal is forced under high pressure into precisely machined durable metal dies. Sub-division of working methods. Lead alloys, tin alloys, zinc alloys; Aluminium alloys, magnesium alloys; Copper alloys. Piston pump die-casting machines; Compressed air die-casting machines. Number of pieces. (1) The type of casting, (2) the level of die cost, (3) the price of material, (4) the cost when using other methods of production. Comparison of the cost. Stresses in die-casting become evident as heat strains and shrinkage strains. Determination of the "critical" number of pieces (*n*) and of the savings per cent in piece work for die-casting as contrasted with mechanical modes of operation. Gradual transition of cross section. Gradual rounding of inner edges. Correct dimensions for holes. Points to be watched. Provide useful rounding. The parting line must be correctly located. Aim at projecting letters or figures. Avoid expensive undercutting. Subsequent treatment. Deburring. Thread cutting Short, easily removable, seams of burrs. Holes should be chamfered. Precision. The deviations from normal size depend on (1) the accuracy of finish of the die, (2) the expansion of the die by heating during the operation and the shrinkage of the die-castings, (3) the position of the movable die parts during pouring, (4) the wear of the die during use, (5) the dimensional stability of the alloy used. Appearance. Nature of surface. Worn dies. Ejector pins. Exploitation of material.

MATERIALS, MATERIAL TESTING.

Tin Economy in Plain Bearings, by P. T. Holligan. (*Met. Ind., July 31, 1942, Vol. 61, No. 5, p. 66*).

This paper elaborates the principles underlying Ministry of Supply Publication P.B.1 (B.N.F. Serial 24,559, see B.N.F. Bulletin 154, April, 1942, p. 108) which set out recommendations of a Technical Advisory Committee aiming at halving the consumption of Sn in bearings.

(*Supplied by the British Non-Ferrous Metals Research Association*).

Cold-Rolled Stainless Steels in Aircraft, by Russell Franks and W. O. Binder. (*Mechanical Engineering, August, 1942, No. 8, Vol. 64, p. 589, 10 figs.*).

The properties of the cold-rolled stainless steels as related to lightweight high strength structure. Recent improvements obtained by slightly changing their composition and by heat treating to relieve internal stress resulting from cold work. The steels to be considered are the 18 per cent chromium, 8 per cent nickel steel; the 17 per cent chromium, 7 per cent nickel steel; and the 17 per cent chromium, 5 per cent manganese, 4 per cent nickel steel. Tension and compression properties of the steels. Stress-strain curves for 18 per cent chromium, 8 per cent nickel steel. Tangent modulus curves derived from stress-strain curves. Stress-strain curves for 17 per cent chromium, 7 per cent nickel steel, and tangent modulus curves. Application of cold-rolled stainless steel to aircraft. Stress-strain curves for steel containing 17.52 per cent chromium, 4.34 per cent nickel, 5.43 per cent manganese, 0.27 per cent silicon, and 0.12 per cent carbon and tangent modulus curves. It is necessary to control the composition of the steels and the amount of cold work applied to them to preserve good ductility with high strength.

MEASURING METHODS AND APPARATUS

Details of a New System of Crack Detection. (*Sheet Metal Industries, October 1942, Vol. 16, No. 186, p. 1557, 1 fig*).

A new method of crack and flaw examination, utilising ultra-violet light and a fluorescent material. A non-fluorescent material illuminated with ultra-violet light will appear black or purple, depending upon the nature of the material; a crack or flaw in that material, if filled with a fluorescent substance, will glow with a characteristic colour. The system has been developed by Colloidal Research Laboratories, Ltd., 66-70, Petty France, London, S.W.1. Advantages: (1) The method may be used with equal efficiency with ferrous or non-ferrous materials; (2) detection is positive without eye-strain; (3) the specimens are degreased, thus telescoping two operations; (4) unskilled labour can be employed; (5) specimens are not stained, and (6) no additional treatment is necessary, as, for example, demagnetising or cleaning.

X-Ray of Aircraft Castings: Its Control and Value, by B. C. Boulton. (*J. Aeronautical Sciences, June, 1942, Vol. 9, No. 8, p. 271*).

A detailed investigation of the value and technique of radiography in the production of aircraft parts. Including the conclusions reached from statistical analysis of results of radiographing a total of several hundred thousand castings (including Mg-base, Al-base and steel) and a study of the relationship between mechanical properties and defects shown in radiographs.

(*Supplied by the British Non-Ferrous Metals Research Association.*)

The Measurement of Torsional Vibrations, by R. Stansfield. (*Engineering, August 28, September 4, 1942, Vol. 154, Nos. 3998, 3999, pages 178, 198, 12 figs.*).

Need for more precise measurements of torsional oscillation amplitudes, particularly those above 2,000 cycles or 3,000 cycles per minute. The most important published development in electrical instruments for measuring vibrations is the M.I.T. (Massachusetts Institute of Technology) Sperry apparatus, described at a meeting of the Institute of Aeronautical Sciences in New York in 1936. Details of an electromagnetic pick-up unit built for the same purpose by the Chrysler Corporation. The apparatus here described was developed from the Chrysler unit applied to the Standard-Sunbury engine indicator, which combines the use of either a direct or an integrated output with a cathode-ray tube unit, the integrating circuit enabling the orthodox type of angular deviation record to be obtained.

Temperature Measurement, (Part 1), by A. Linford. (*Machinery Lloyd, September 19, 1942, Vol. XIV, No. 19, p. 38, 8 figs.*).

The accurate measurement of temperature is of great importance in the vast majority of industrial processes, but its determination is frequently a problem of some complexity. "Accurate" liquid-expansion thermometer with head and capillary fully compensated for ambient temperatures, head effect and external pressures. "Teddington" 2-in. dial vapour-pressure thermometer for refrigeration plant. Typical mercury-in-steel thermometer. Method of compensating for changes in temperature of the capillary tube and the Bourdon tube element. Compensation for ambient temperature variations. Diagram of vapour pressure thermometer. Diagram to illustrate the fundamental difference between liquid expansion, constant volume gas, and vapour pressure thermometers.

Inspecting Bolts, Nuts and Screws. (*The Machinist, September 5, 1942, Vol. 86, No. 21, p. 496, 12 figs.*).

(1) Material is received in the form of wire in coils. (2) Spectroscopic analysis is made of material. (3) Cold heading is done after material has passed the preliminary tests. (4) Line inspection at the boltmaker. (5) Precision threads are essential in some instances especially for aircraft bolts. (6) A magnetic test for flaws is made in a special machine. (7) Hardness tests are made on many bolts following heat treatment. (8) Microscopic inspection of surface condition is required on some bolts and screws, especially for aircraft work. (9) Completed parts are placed in tote pans on a gravity conveyor which delivers them to the final inspection department. (10) Slowly moving belts are used for sorting and inspecting nuts when specifications do not require more exacting tests. (11) Aircraft bolts and screws are inspected on ordinary flat top benches. (12) Aircraft nuts are inspected in a special set-up.

METALLURGY.

Sintered Parts. (*Automobile Engineer, July, 1942, Vol. XXXII, No. 425, p. 266*).

Cost of quality. Steel components. Effects of graphite. Physical properties. Experimental work. Temperature effects. High temperatures. Temperature and pressure. Pressing time. Effect of annealing.

PLASTIC MATERIAL.

Plastic Jigs, Forms and Dies. (*Machinery, September 10, 1942, Vol. 61, No. 1561, p. 289, 10 figs.*).

Duralumin sheet-metal part formed on a thermo-setting plastic die under a large hydraulic press. Construction of a simple drill jig, in which a plastic nest block and drill plate are assembled in a wooden box. The plastic drill-jig has sometimes replaced that constructed of steel with considerable saving in cost and production time. A drill jig for function boxes together with the mould. A plastic template is used in hammering out the wrinkles of the aluminium air scoops. Combination drill jig and routing template in which the drill bushings are held in metal strips mounted on a plastic form of the required contour. Large plaster shapes from which dies were made for forming sheets of plexiglas. Pouring plastic resin from a converted dough mixer into a plaster mould to produce a plastic router block, which was in use within three hours after the mould was poured.

The Design of Plastic Moulded Parts for Economical Quantity Production. (*Machinery, September 17, 1942, Vol. 61, No. 1562, p. 315, 13 figs*).

Inserts, when properly designed and located, are very useful in mouldings. Their purpose is generally to avoid wear or to take stresses that are usually too great for the plastic part itself ; or to provide electrical conductors. Steel and brass are the most commonly used among the metal inserts. A moulded part with two inserts designed for ejector pins. Location of ribs and bosses relative to the parting line. Louvres and how they are formed. Convenient fastenings.

Plastics in Aircraft Construction, by George W. DeBell. (*Aircraft Engineering, September, 1942, Vol. XIV, No. 163, p. 254, 1 fig.*).

Thermosetting materials. Thermoplastic materials. Wood veneer materials. Design considerations affecting utilisation. Aircraft factors affecting design. (1) temperature, (2) impact strength, (3) weight requirements. Resistance to

wear. Co-efficient of expansion. Moisture absorption. Relative costs. Limitations of each type of material. Tolerances. The laminated thermosetting materials can be machined to approximately the same tolerances as at present used for metal parts, except that ground finishes cannot be produced to the same accuracy as possible with metal. Applicable specifications. Availability. Possible saving of aluminium.

SURFACE, SURFACE TREATMENT.

Metal Coating, by W. J. Cumming. (*Automobile Engineer, August, 1942, Vol. XXXII, No. 426, p. 313*).

Under existing conditions it is quite important to consider what salvage methods can provide the greatest benefit to automotive maintenance. The answer is probably metal coating and hard sufacing, for both methods not only allow the original dimensions to be restored economically, but furnish an added dividend, in many cases, by providing superior wearing qualities in the substitute metal. Metal coating. Foundation surface. Spraying technique. Maintenance work. Porous structure. Cost of process. Non-ferrous alloys. Tungsten carbide.

The Formation and Evaluation of Zinc Coatings. (*Sheet Metal Industries, October, 1942, Vol. 16, No. 186, p.1481, 7 figs.*).

Automatic plant for electro-galvanising steel strip. The plating solutions. (a) The acid solution. (b) The alkaline solution. (c) Other solutions. (d) Bright zinc solutions. Operating conditions for a, b, c, d, Anodes. Zinc plating on aluminium. Zinc-cadmium alloy plating.

The Spraying of Metals, by W. E. Ballard. (*Iron Age, May 21, 1942, Vol.149, No. 21, p.50*).

A survey of the development of the process, applications and future outlook.

(*Supplied by the British Non-ferrous Metals Research Association.*)

Sprayed Metal Bearings. (*Iron Age, June 25, 1942, Vol. 149, No. 26, p.52*).

An account of tests by H. Shaw and short notes on recent American work on "Oilless" sprayed-metal bushings and liners.

(*Supplied by the British Non-ferrous Metals Research Association*).

Rust Proofing of Ferrous Metals in Light Engineering Practice, by H. Silman. (*Sheet Metal Industries, October, 1942, Vol. 16, No. 186, p. 1531, 6 figs.*).

Cementation and diffusion process. Calorising. Chromising. Ihrigising. Cladding. Stainless cladding. Aluminium cladding. Paints. Inhibitive paint primers. Painting of galvanised surfaces. Temporary rust prevention. Special coatings. Rubber covering. The testing of protective finishes. Accelerated tests. Thickness of coatings.

TECHNICAL EDUCATION.

A Critical Review of Education and Training for Engineers (*The Journal of the Institution of Electrical Engineers, Part 1, September, 1942, Vol. 89, No. 21, p. 376, 1 fig.*).

Outline of the pre-war education system of England and Wales, with particular reference to the education and training of engineering personnel.

Qualities and training required for various grades of work. Discussion of the pre-war system of engineering education and training, and suggestions for its improvement. Short-term post-war problems.

The Entry of Juveniles into Employment, by B. N. Seear. (*Labour Management, August, September, 1942, p. 95*).

Day continuation school at Street. Curriculum and staff. Apprenticeship in the factory. Co-operation between education and industry.

WELDING, BRAZING, SOLDERING.

Welding Developments. (*Aircraft Production, October, 1942, Vol. IV, No. 48, p. 591, 3 figs.*).

Anti-glare goggles for aluminium welding. Air-cooled welding torch. Rotary worktables.

SURFACE FINISH

Report of the Research Department of the Institution of Production Engineers, 36 Portman Square, London, W.1.

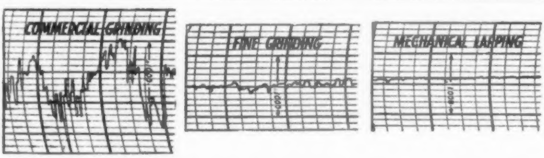
by DR. GEO. SCHLESINGER, *Director.*

January, 1942

Price 15s. 6d. nett (For members 10s. 6d.) *Copyright*

CONTENTS

Principle factors involved. Results of measurements. The influence of the scratching action of the stylus of tracer instruments. (a) Classification of surfaces without measurement. (b) Quantitative photomicrography. Dimension and surface roughness of gauges. The instruments used. Investigation of surface roughness in the U.S.A.



Showing Quality of Surface and Manufacturing Process.

Review from MACHINERY—*England, April* 16, 1942.

The subject of surface finish in relation to dimensional accuracy, fit, lubrication and wear of operational components has been one of the most important questions that have occupied investigators in recent years on both sides of the Atlantic.

One of the chief problems has been the quantative determination of the amount and conditions of surface finish and a unit of roughness.

The results presented in the report make a most important contribution to the development of a technique of basic importance in engineering production, and, in a remarkable table occupying 48 pages, the findings are collected and compared in respect to 500 surfaces of all kinds.

The aims of the research, the chief of which was to replace the loose descriptive methods by a more definite system for measuring surface roughness, appear to have been completely reached.

Review from ENGINEERING—*July* 24, 1942.

The importance of the matter, and, no doubt the very complete basis for a consideration of the subject which is furnished by this report, has led to the appointment of a committee of the British Standards Instutition to consider the formulation of standards.

For the purposes of this investigation the Institution appealed to a wide range of manufacturers of the finer grades of engineering product and obtained typical specimens of finished work from 19 British firms. The most important instruments, both for the measurement of surfaces and for their comparison, were also lent by British and American makers.

Those who have hitherto given little attention to the matter will find the report an admirable guide to the whole subject of surface finish.

Review from AIRCRAFT PRODUCTION, *May* 1942.

Although engineers have realised for some considerable time the importance of the quality of surface finish for both moving and static parts, practical engineering data and technical literature have not hitherto been available for those interested. Consequently the Research Department of the Institution of Production Engineers are to be congratulated on their foresight in making the first thorough investigation of the subject in this country. The results of the experiments have been collected and arranged as practical, useful measuring units in a table giving data describing approximately 500 surfaces of all types. The instruments used for measurement included the most modern tracer and optical apparatus.

Review from MECHANICAL ENGINEERING—*July* 1942 (*American Society of Mechanical Engineers*).

Dr. Schlesinger's book is particularly welcome because it is one of the few books in the English language on the timely subject of surface finish and because it brings together much new and hitherto unpublished information.

The study was undertaken to provide standards for the measurement and rating of metal surfaces and to summarise standard practice in Great Britain as regards the type of finish which is applied to various machine parts by reputable manufacturers.

The tabulation of the results of these measurements in the last 48 pages of the book is one of its most valuable features.

One of the most interesting sections of the book deals with the tolerances and finishes on plug and snap gauges and on gauge blocks. The finish measurements on these tools are quite enlightening.

STEWART WAY, *Research Laboratories, Westinghouse Electric Mfg. Co., East Pittsburgh*

The Council of the Institution

OCTOBER, 1942

PRESIDENT: SIR ERNEST LEMON, O.B.E.

DEPUTY-PRESIDENT: LORD SEMPILL, A.F.C.

CHAIRMAN OF COUNCIL: H. A. HARTLEY.

VICE-PRESIDENTS: C. D. Alder, A. Bailey, J. L. Bennet, J. W. Berry, A. Brown, H. D. S. Burgess, N. J. Cottell, J. S. Daniels, J. W. Davies, J. Finley, I. Garvie, H. J. Gibbons, W. A. Harriman, M. B. E., S. R. Howes, R. Kirchner, Major C. W. Mustill, M.B.E., A. E. Newby, M.B.E., J. R. Pearson, R. D. G. Ryder, Mark H. Taylor.

PAST-PRESIDENTS: G. E. Bailey, C.B.E., Sir A. Herbert, K.B.E., Viscount Nuffield, G.B.E.

PAST-VICE-PRESIDENTS: J. H. Bingham, J. T. Kenworthy, N. V. Kipping, W. Puckey.

ADDITIONAL SECTION REPRESENTATIVES: E. P. Edwards, *Birmingham*; J. E. Baty, G. H. Hales, F. Halliwell, J. Blackshaw.

ORDINARY MEMBERS: R. Broomhead, W. F. Dormer, H. A. Drane, T. Fraser, T. France, E. W. Hancock, M.B.E., J. A. Hanney, E. J. H. Jones, F. A. Pucknell, H. Schofield, M.B.E. Ph.D., J. R. Sinclair, F. White, F. Williams, T. H. Wright.

Section Hon. Secretaries:

Birmingham: F. C. White, "Heath House," Welston, Nr. Coventry.

Cornwall: J. Arthur, "Clifton," Mount Pleasant Road, Camborne, Cornwall.

Coventry: A. W. Buckland, 3, Cawston Way, Bilton, Rugby.

Eastern Counties: D. Braid, Reavell & Co., Ltd., Raneleagh Works, Ipswich.

Edinburgh: P. H. Lee, The North British Rubber Company, Castle Mills, Edinburgh, 3.

Glasgow: W. Crawford-Miller, "Lishore," Bridge of Weir, Renfrewshire.

Leicester and District: H. S. Burdett, 18, Stanfell Road, Leicester.

London: R. Hazleton, 36, Portman Square, London, W.1.

Luton and Bedford: R. M. Buckle, 238, Cutenhoe Road, Luton, Bedfordshire.

Manchester: F. W. Cranmer, Associated British Machine Tool Makers, Ltd., Lloyds Bank Buildings, King Street, Manchester.

North Eastern: J. Nicod, A. Reyrolle & Co. Ltd., Hebburn-on-Tyne, Durham.

Northern Ireland: D. H. Alexander, College of Technology, Belfast.

Nottingham: L. Shenton, "The Anchorage," Shaftesbury Avenue, Sandiacre, Notts.

Preston: R. G. Ryder, Thos. Ryder & Sons, Ltd., Bolton, Lancs

Sheffield: J. P. Clare, St. James' Chambers, 38, Church Street, Sheffield, 1

Southern: J. F. W. Butler (Acting Secretary), Vickers-Armstrong, Ltd., Supermarine Works, Hursley Park, Nr. Winchester.

South Wales and Monmouthshire: J. Vaughan, 131, Penarth Road, Cardiff.

Sydney (New South Wales): J. M. Steer, 260/262, Kent Street, Sydney.

Western: H. D. Glover, 63, Trelawney Road, Bristol, 6.

Yorkshire: D. G. Watkinson, 3, Austhorpe Lane, Whitkirk, Leeds.

THE INSTITUTION OF PRODUCTION ENGINEERS

36, Portman Square, London, W.1

PUBLICATIONS OF THE RESEARCH DEPARTMENT

February, 1942

REPORT ON SURFACE FINISH, price **15/7** post free*

Part II. ACCEPTANCE TEST CHARTS FOR MACHINE TOOLS, price **5/7** post free

Earlier Publications

ACCURACY IN MACHINE TOOLS: How to measure and maintain it, price **3/3** post free

Part I. ACCEPTANCE TEST CHARTS FOR MACHINE TOOLS, price **5/6** post free

Also the following reports which appeared in the Institution's *Journal*, copies **5/-** each, post free

	Vol. No.		
Cutting Tools	XVIII, 11	1939	February
Dial Gauge and Its Use	XVIII, 11	1939	November
Research on Surface Finish (Preliminary Report)	XIX, 3	1940	March
Substitute Materials	XIX, 7	1940	August
Modern Measuring Instruments and the Principles of their Design	XIX, 9	1940	September
The Rebuilding of Old Machine Tools for the Requirements of War	XIX, 10	1940	October
The Effect of Reversing Flat Leather Belts	XX, 5	1941	May
The Natural Sag of Test Mandrels and its Consideration in Checking Machine Tools	XX, 1	1941	January
The Influence of Warming-up on Capstan and Combination Turret Lathes ..	XX, 4	1941	April
Taps, Efficiency, and Correct Design ..	XX, 6	1941	June

*Price to Members only, 10/7

S

g*
E

nd

E

's

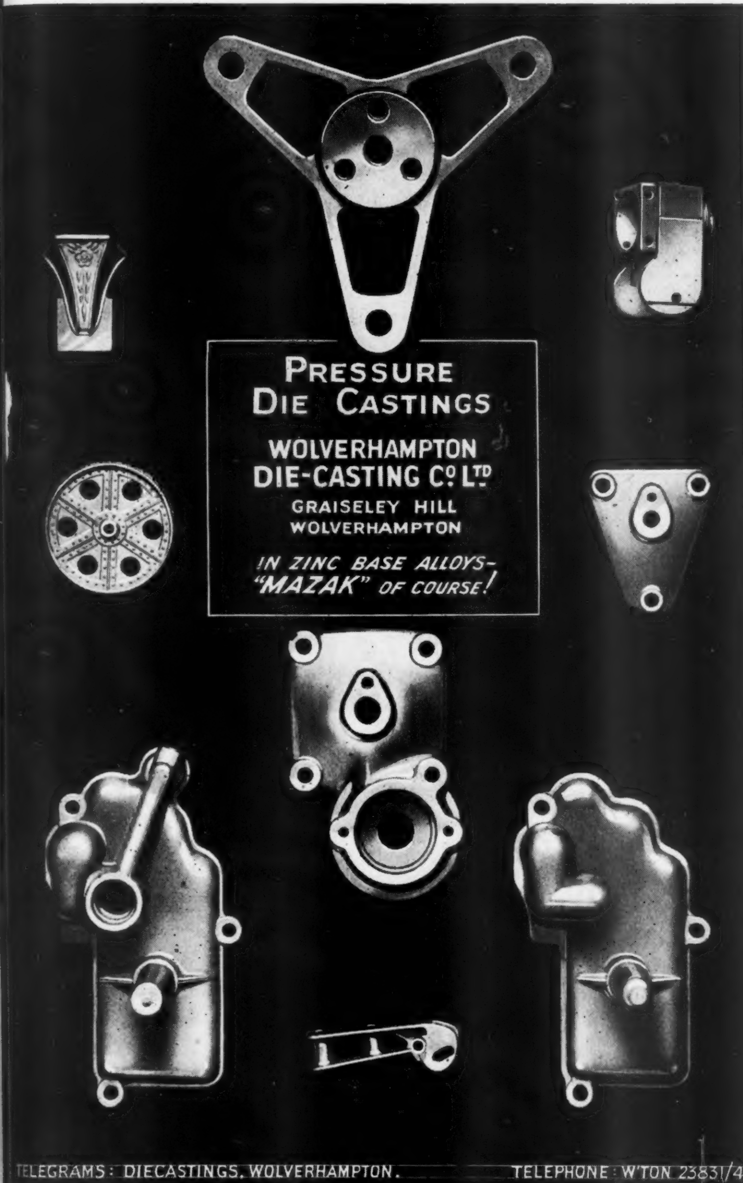
—

r

r

—

TELEC


PRESSURE
DIE CASTINGS
WOLVERHAMPTON
DIE-CASTING C^O. L^TD.
GRAISELEY HILL
WOLVERHAMPTON
IN ZINC BASE ALLOYS-
"MAZAK" OF COURSE!
TELEGRAMS: DIECASTINGS, WOLVERHAMPTON.
TELEPHONE: W'TON 23831/4

All communications regarding advertisements should be addressed to the Advertising Managers, T. G. Scott & Son, Ltd., Talbot House 9 Arundel St., London, W.C.2. Phone: Temple Bar 1942
Printed by Richard Bates Limited, 9-13, Stockton Street, All Saints, Manchester 15.

T
D
L
S

O.
O.
N.

z Managers,
e Bar 1942
er 15.